# COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

NOV 26 1937

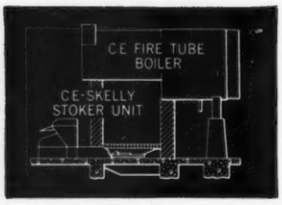
Vol. 9, No. 5 | NOVEMBER, 1937 | 25c a copy

One of the mills at the 12th Street Station, Richmond, Va.; see page 18

## "Topping" 12th Street Station, Virginia Electric and Power Company

## Steam Contamination—III

## A.S.M.E. and A.I.M.E. Hold Joint Fuels Meeting




**CAPACITY—1000 LB. OF STEAM PER HR.**

*Typical C-E Unit for small boiler plants—factories, dairies, laundries, greenhouses, hospitals, hotels and buildings. 1000 such units would be required to produce the same amount of steam as the C-E Unit shown below.*

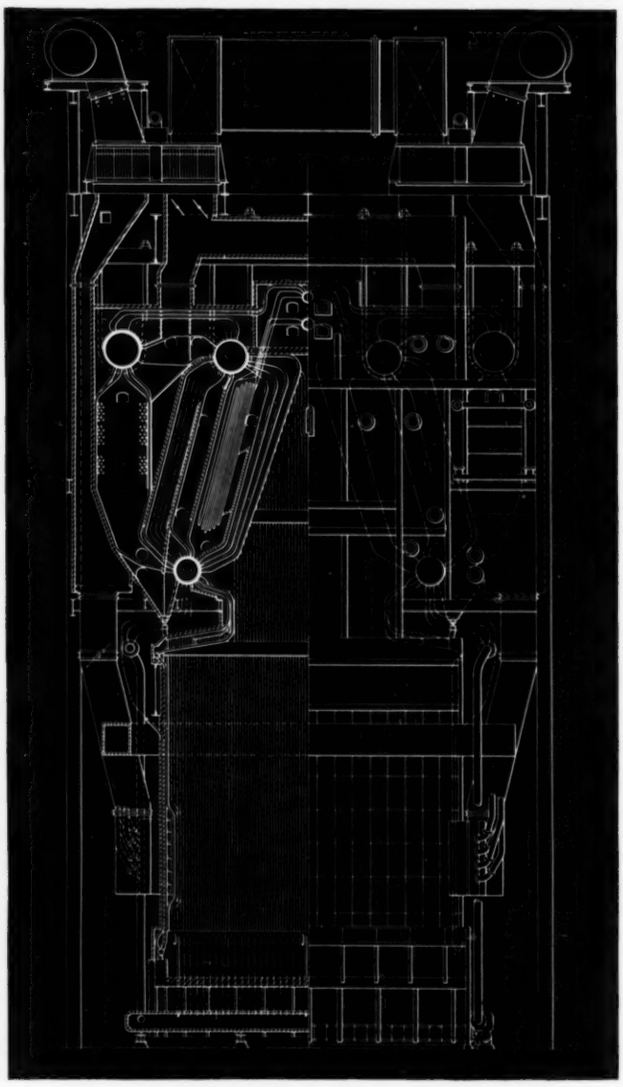
# MODERN

# STEAM GENERATING UNITS

Combustion Engineering is the only manufacturer that has installed complete steam generating units for the range of capacities illustrated by the two units shown.

C-E Units, comprised of various types of C-E Boilers, Furnaces, Fuel Burning and related equipment, are available for all requirements within this range. C-E experience with fuel burning and steam generating problems is correspondingly broad.

You can purchase a C-E Unit with certainty that the various elements of equipment comprising it will be the types best adapted to your particular plant, load and fuel conditions. You can also be certain that your C-E Unit will produce whatever steam you need at the lowest possible cost. These are the reasons why so many leading industrials and utilities are consistent users of C-E equipment.



**CAPACITY—1,000,000 LB. OF STEAM PER HR.**

*C-E Unit recently installed in a utility plant. This is the first and only steam generating unit in the world to be designed for the capacity indicated. Its height is equivalent to a 10-story building.*

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# COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME NINE NUMBER FIVE

# CONTENTS

## FOR NOVEMBER 1937

### FEATURE ARTICLES

"Topping" 12th St. Station, Virginia Electric and Power Company — *by F. H. Spies* ..... 18

Steam Contamination—III Determination of Steam Quality — *by Sheppard T. Powell* ..... 25

A.S.M.E. and A.I.M.E. Hold Joint Fuels Meeting ..... 32
- Chain- or Traveling-Grate Stokers — *by Gosta Anbro* ..... 32
- Coal Selection for Underfeed Stokers — *by J. E. Tobey* ..... 33
- Selecting Coal for Pulverized Firing — *by B. E. Tate* ..... 33
- Coal Selection — *by R. A. Sherman* ..... 34
- Interpretation of Laboratory Coal Tests and Sampling Methods — *by G. B. Gould* ..... 35
- Segregation in Handling of Coal — *by David R. Mitchell* ..... 36
- The Chemical Treatment of Coal and Coke — *by P. Nicholls* ..... 36

The Flow of Water and Compressed Air in Pipes — *by F. M. Van Deventer* .... 38

Steam Power Developments — *by C. W. E. Clarke* ..... 41

### EDITORIAL

Professional Engineers View Unionism ..... 17

### DEPARTMENTS

Steam Engineering Abroad ..... 45

New Catalogs and Bulletins ..... 50

Equipment Sales—Boiler, Stoker and Pulverized Fuel ..... 51

Advertisers in This Issue ..... 52

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Combustion is published monthly by Combustion Publishing Company, Inc., a subsidiary of Combustion Engineering Company, Inc., 200 Madison Avenue, New York. Frederick A. Schaff, President; Charles McDonough, Vice-President; H. H. Berry, Treasurer; G. W. Grove, Secretary. It is sent gratis to consulting and designing engineers and those in charge of steam plants from 500 rated boiler horsepower up. To others the subscription rate, including postage, is $2 in the United States, $2.50 in Canada and Great Britain and $3 in other countries. Single copies: 25 cents. Copyright, 1937, by Combustion Publishing Company, Inc. Printed in U. S. A. Publication office, 200 Madison Avenue, New York. Issued the middle of the month of publication.

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# *On Rapid Load Swings*

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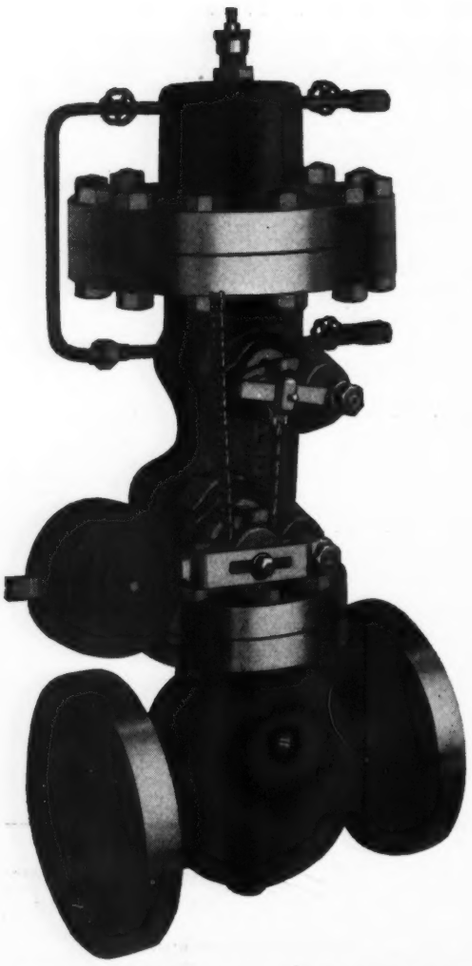

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SYSTEM OF BOILER FEED CONTROL

BRANCH PLANTS IN CANADA – ENGLAND – FRANCE – GERMANY – AUSTRIA – ITALY – SALES AND SERVICE REPRESENTATIVES IN PRINCIPAL INDUSTRIAL CENTERS THROUGHOUT THE WORLD

# EDITORIAL

## Professional Engineers View Unionism

DURING the past five years vast social and economic changes have been wrought, and the end is not in sight. It matters little whether or not one approves of them; they are here and must be faced by engineers from the standpoint of their effect upon the profession. One of the most potent forces of this social evolution is the drive of organized labor. That the professions are immune to its influence is controverted by reports of engineers having been coerced or induced to join its ranks and by the occasional utterances of certain groups within engineering circles.

With due credit to the aims and accomplishments of labor unions over a long period of years, the position of the engineer is somewhat unique and warrants the fullest discussion in order that it may be clearly defined. This is especially important in view of the existing laws affecting labor.

The subject is one that has received scant attention within the founder engineering societies which, in general, have adhered to their original aims of meeting the technical and allied needs of their respective memberships. It is not surprising, therefore, that the National Society of Professional Engineers, unhampered by tradition and dedicated to promoting and safeguarding the professional status of engineers, should assume the lead in discussing this question at its Annual Convention in New York last month.

Outstanding in this discussion was the paper by Raphael J. Smyth, former vice president of the New York State Society of Professional Engineers, who pointed out that a license to practice professional engineering is a revokable commission conferred by the State to safeguard the life, health and property of its people; and that the recipient, by acceptance of the license, takes an implied oath to discharge faithfully the obligations involved. These obligations, Mr. Smyth pointed out, would be violated by active participation in, or passive support of, a strike involving the interruption of water, power, light, transportation or food supply to a community. An anomalous condition exists in that the State, by its license law, requires the professional engineer to safeguard life, health and property; yet both the National and the New York State Labor Relations Acts sanction, in the absence of contrary judicial interpretation, the coercion of employees by Labor. This, in fairness to engineers, should be corrected.

Mr. Smyth tersely summed up the situation by stating that there is offered a ringing challenge to the engineering profession to protect its members from coercive pressure and that the Society of Professional Engineers, in a spirit of amity and good will, with no animosity toward either of the existing divisions of organized labor and without questioning the right of a member freely to join or not to join a labor organization, must take a defensive position to the end that freedom of action of licensed professional engineers may be safeguarded.

The reactions to Mr. Smyth's paper indicated that he voiced the opinions of the majority present.

Following closely upon the meeting of the Society of Professional Engineers, the National Board of Directors of the American Association of Engineers met at Chicago and took cognizance of the movement toward unionism within the engineering profession. It reaffirmed the resolutions adopted in 1919, stating (1), that the engineer is the medium through which both capital and labor are used in production and industrial development; (2), that production should be increased, not limited; (3), that the profession cannot support strikes or lockouts that may benefit any class at the expense of the nation as a whole; (4), that rewards should be according to ability, initiative and constructive effort; and (5), that the engineer believes in basing his claims for proper and just reward for his services upon the justice of the facts presented. The Board, disclaiming any opposition to trade unionism, as such, expressed the opinion that the engineer cannot subscribe to the tenets of both an organization of professional men and those of a trade union.

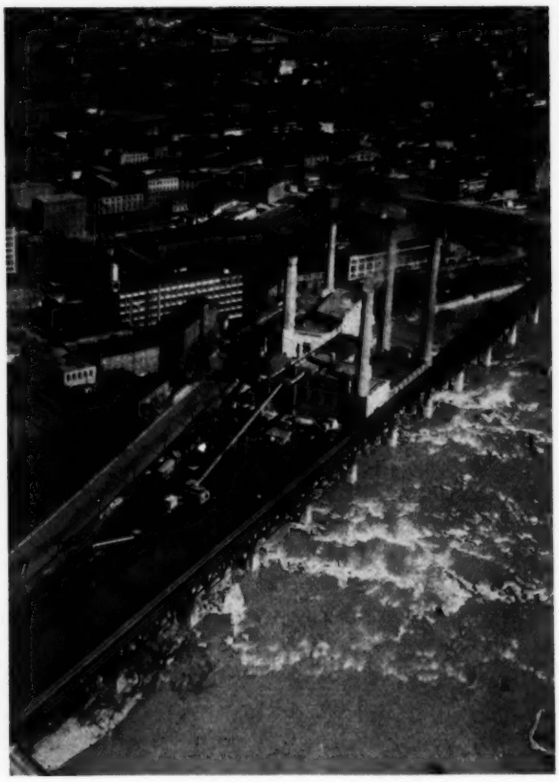
The actions by these two national societies are a forward step in defining the position and obligations of the engineer. They also offer a sound basis for constructive thinking and discussion. One might add that the engineer, as a creative individual bent upon utilizing the forces of nature to the best advantage, does not look with favor upon that which restricts his field of action. Furthermore, while it is possible collectively to evaluate manual effort, the product of one's brain, as in the case of most engineering work, does not lend itself to any definite standard of measurement.

It is believed that many of these facts, if squarely placed before intelligent labor opinion, would receive full appreciation.

# "TOPPING" 12th ST. STATION, Virginia Electric and Power Co.

**By F. H. SPIES**
**Steam Plant Efficiency Engineer,**
**Virginia Electric and Power Co.**

**By the addition of a 900-lb boiler and high-pressure turbine exhausting to the old 200-lb units the average station heat rate has been lowered by over 38 per cent. This installation is described in detail, including several novel features, and test results, as well as operating performance, of the high-pressure steam generating unit are included.**

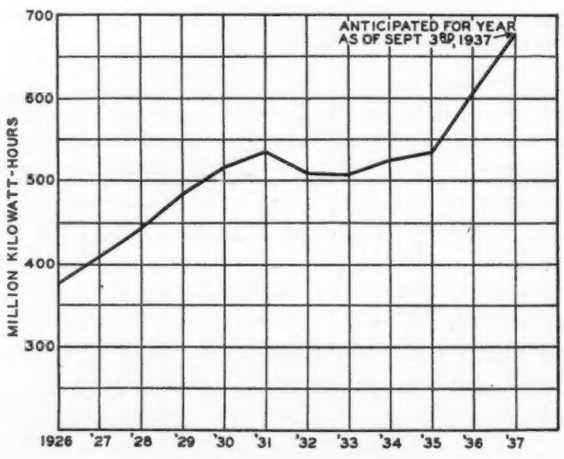


**Aerial View of Station**

THE 12th Street plant is one of the two main generating stations on the Virginia Electric and Power Company system which supplies power and light to 115,000 domestic consumers, 800 industrial establishments and 21,500 miscellaneous business enterprises, and power for the operation of electric railways in several of the larger cities. In 1936 the total electric load on the system was 605,000,000 kwhr, of which approximately 200,000,000 kwhr was supplied by the 12th Street plant. The curve below indicates the growth of system load since 1926.

*Early Developments*

This plant is composed of two stations—No. 1, the hydro station, and No. 2, the steam station. No. 1 Station was built at its present location on the north bank of the James River about 1900. The original installation of nine 1000-kw water-wheel units is approximately what we have today, although some of the original wheels and d-c generators have been replaced by modern a-c equipment in the past ten years. Five of the original water-wheel generators were also equipped with 200-lb auxiliary Corliss steam-engine drives, the steam being furnished by hand-fired water-tube and hrt boilers located opposite the hydro station and in the space which is now occupied by the plant shops and storeroom. The stack erected for this installation is, to the best of our knowledge, the first commercial concrete stack ever built.




**System load growth since 1926**

A 3000-kw, 2300-volt, 3-phase, 60-cycle steam turbine-generator with jet condenser was installed in the north end of No. 1 Station in 1907 and a similar 5000-kw machine in 1910. These units were supplied with steam at 200 lb from the aforementioned battery of boilers. Increasing district load and unreliability of water power necessitated further extension of the steam power.

In 1912 a new steam station, known as No. 2, was erected. This contained a 7500-kw, 2300-volt, 3-phase, 60-cycle, turbine unit equipped with a surface condenser. In 1918 a 20,000-kw, 13,200-volt, 3-phase, 60-cycle unit with surface condenser was installed and a second similar

unit followed in 1925. All of those units were supplied with 200-lb, 535-F steam. The condenser circulating water normally has a gravity flow from the hydro plant canal through the condensers to the river. Four high-water and two low-water circulating pumps have been installed to insure adequate circulating water during flood and extreme low-water stages of the river.

Shortly after the erection of No. 2 Station the steam equipment, excepting the two turbine-generator units, was removed from No. 1 Station. That is, the auxiliary steam drives of the water-wheel generators and the hrt boilers were retired. Four of the water-tube boilers were moved to the 200-lb boiler room of No. 2 Station and the 5000-kw and the 3000-kw steam turbines were connected by a 200-lb steam header to this source of steam.

The boiler room was enlarged as generating equipment was added and, today, totals sixteen 600-hp water-tube boilers with superheaters operating at 200 lb gage and 535 F total steam temperature. These boilers are fired by seven-retort underfeed, inclined-grate, variable-speed, motor-driven stokers and are equipped with soot blowers, air-cooled dump grates and elementary combustion control. The furnaces are refractory lined.

Auxiliary equipment for the 200-lb steam plant consists of alternate steam and motor drives on forced-draft fans, condensate pumps and house water pumps, and steam drives only on the four boiler feed pumps. Miscellaneous equipment such as plant compressors are induction-motor driven.

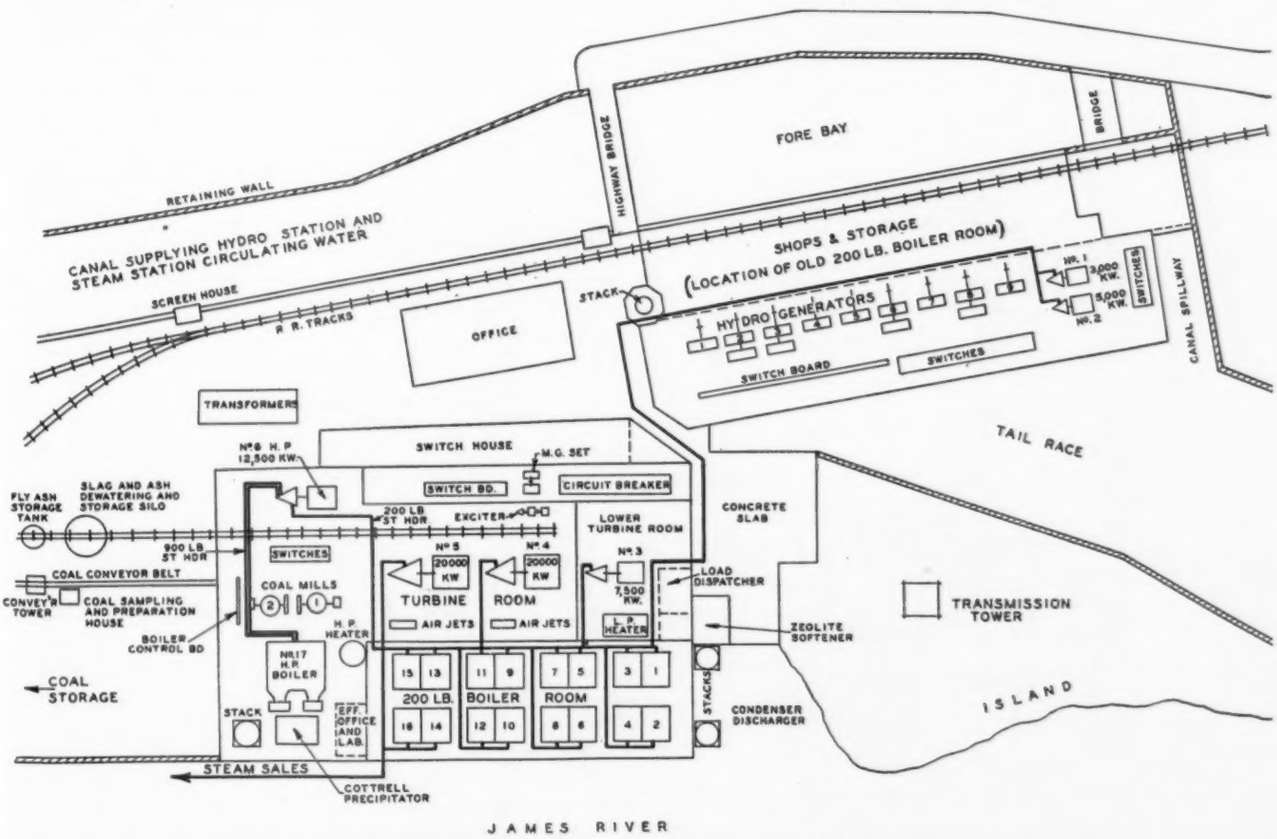
In 1936 the Company was confronted with the problem of supplying a rapidly increasing electric load. Extension of the transmission system, development of hydro sites and steam station additions were studied from system load, district load and economic angles.

Extension of the transmission system would have necessitated reliance on already overloaded neighboring utilities for a source of prime power, and hydro developments did not afford the security believed necessary without a reserve of equivalent steam generating capacity. Hence, these considerations were disregarded in favor of steam station expansion.

### *1936 Extension at Richmond*

Selection for the expansion had to be made between the station located in Richmond and that in Norfolk. The latter, a 400-lb installation, is relatively efficient and of sufficient capacity to carry its district load. The Richmond plant, on the other hand, operated at 200 lb and, although the auxiliary and electric generating equipment was fairly efficient, the steam generating equipment was inefficient and inadequate for the Richmond district load. Both plants afforded equal return as far as a straight condensing addition was concerned, but the Richmond plant was ideally set up for a "topping" unit. As this type of construction would cost much less in dollars per kilowatt of thoroughly modernized capacity it was selected over a straight condensing addition. The return on this type of construction was estimated to be about 15 per cent greater at Richmond's 200-lb station than at Norfolk's 400-lb station.

A steam generating unit of 450,000 lb per hr maximum capacity at 900 lb pressure and 835 F total steam temperature and a 12,500-kw (15,000-kva), non-condensing




**Plan of station showing hydro plant, low-pressure plant and high-pressure extension**

"topping" turbine, exhausting without reheating at 200 lb and 535 F into the main steam header of the existing station, were selected as most practical.

The Stone & Webster Engineering Corporation was retained in charge of designing, engineering and construction. Work was begun during February 1936 and completed the latter part of September of the same year, the boiler being fired October 13, 1936.

The plan of the station shows the hydro plant, the 200-lb equipment and the high-pressure extension.

### *High-Pressure Steam Generating Unit*

The 24,930-sq ft, 925-lb (design pressure, 900 lb operating) boiler is of the Combustion Engineering three-drum bent-tube type with an additional dry drum containing a steam washer of the bubble type, which on test has provided steam of about 0.5 ppm purity. The boiler is set over a completely water-cooled furnace made up of 10,260 sq ft of 3-in. plain tubes on $3^1/_2$-in. centers. The furnace, which has an effective volume of 19,400 cu ft, is of the intermittent slag-tap type and is fired tangentially by eight horizontal burners, two to each corner.

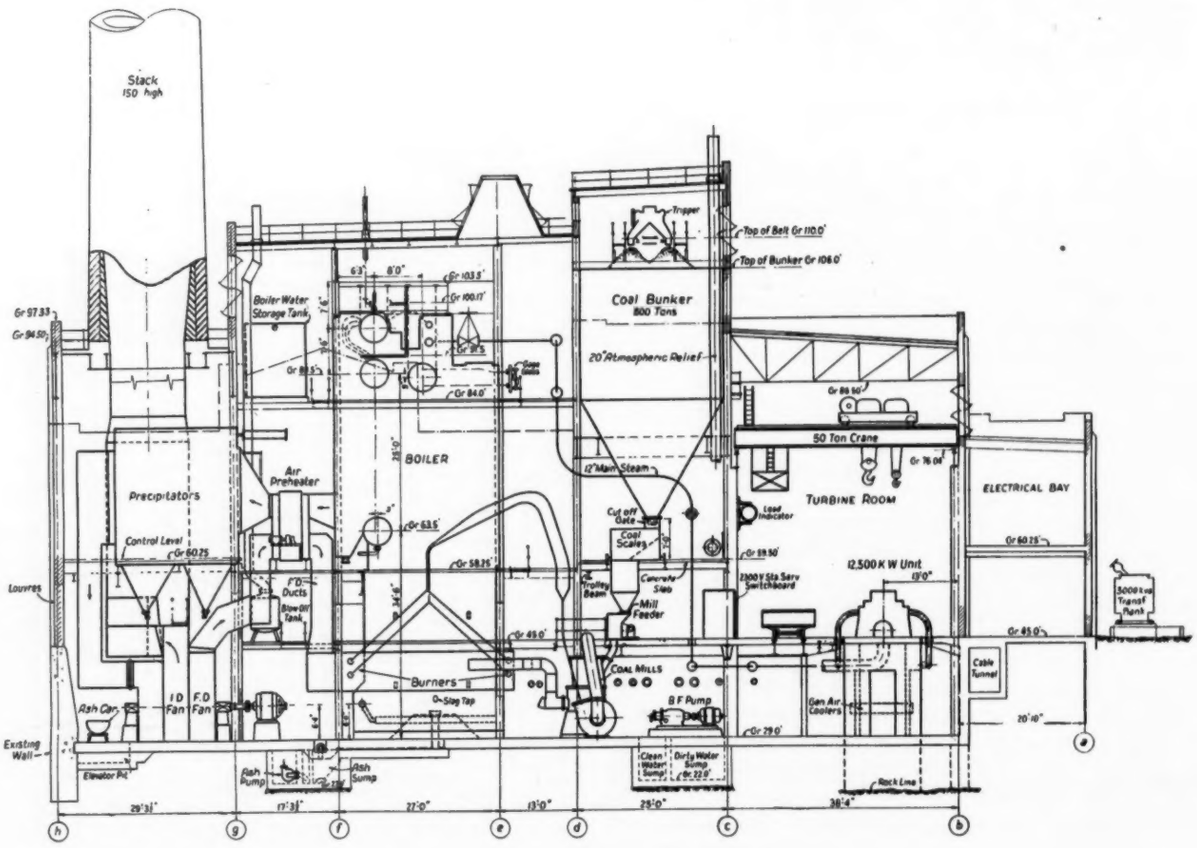
These are supplied by two 54-in., three-roll, CE-Raymond bowl mills having integral exhausters, each of which supplies four burners. The raw coal feeders are located on the operating floor above the mills and the coal flows from overhead bins to Richardson automatic scales which discharge to hoppers over the feeders. The mills are supplied with heated air from the secondary air duct and have atmospheric openings for tempering the air mixture to maintain a temperature of around 160 F at the discharge.

The superheater, designed for a steam temperature of 835 F at rated capacity, is of the Elesco convection type and is located in the first pass. Its elements are 2 in. diameter and the heating surface is 8650 sq ft. A bypass damper, located at the upper end of the second pass of the boiler, provides automatic regulation of the outlet steam temperature by controlled gas flow over the superheater. This damper, actuated and piloted by Hagan control, has been successful in regulating the steam temperature to within 5 deg F at 830 F. Although in a region of high gas temperature, the damper seems to be operatively free at all times and has not become warped.

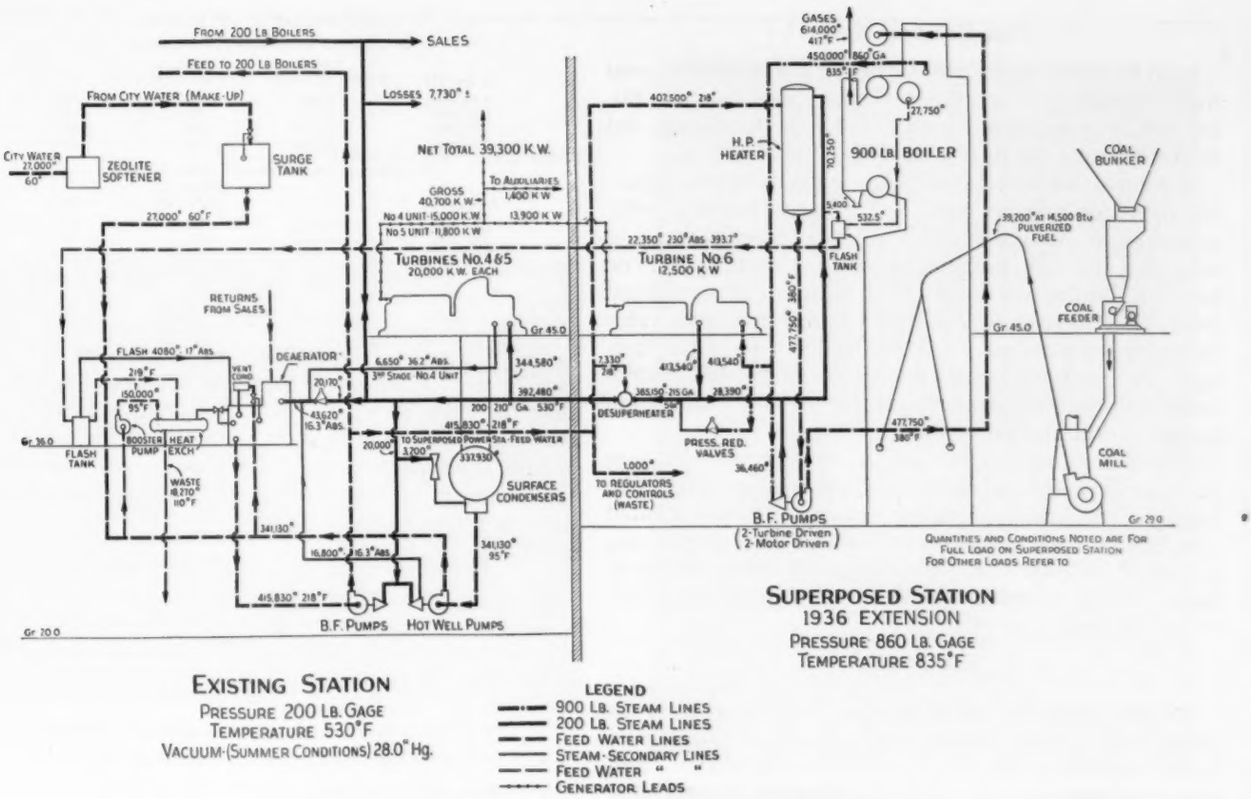
Two air heaters of the Ljungstrom regenerative type, each of 16,100 sq ft heating surface, are mounted on horizontal shafts and supply preheated air to the mills and the furnace.

### *Dual Fans*

The unit is provided with two sets of Sturtevant combined forced- and induced-draft fans, each composed of one forced- and one induced-draft fan element mounted between two bearings on a common shaft. Each set is driven through a flexible coupling by a 700-hp, 13-point, variable-speed induction motor of the slip-ring type. The forced-draft fans are of the single-inlet, single-discharge type and a multivane louvre damper provides air discharge regulation for any given fan speed. The induced-draft fans are also of the single-inlet type and are provided with multivane louvre dampers and adjustable inlet vanes capable of regulating the pressure over a capacity range of 25 per cent. The vanes are set to operate only after the fan is delivering approximately 60




**Section through high-pressure extension**




**Flow diagram for low- and high-pressure equipment**

per cent of its capacity. At this 60 per cent limit the vanes and dampers open together and effect a smooth and gradual sloping curve over the entire capacity range of the fan. These dampers are under full automatic actuation by the combustion control system and give satisfactory draft regulation.

The induced-draft fans exhaust to a 14 ft diameter, 150 ft high superposed perforated radial brick stack, designed to withstand a wind velocity of 100 mph and the effects of 500 F flue gas and prevailing weather conditions.

The Bailey combustion control system regulates, through a master controller, the superheated steam header pressure by control of the primary air, the induced-draft dampers and vanes, the forced-draft dampers and speed of the tandem fans, with steam-flow air-flow readjustments applied to the induced-draft dampers and vanes. The power control cylinders and pilot controls operate from a 60-lb oil- and water-free air supply. A master selector valve provides automatic or manual control of the entire system from the boiler gage board. Individual selector valves permit control from the board of any damper or feeder functioning in the control system.

### *Slag Removal*

Slag removal from the furnace bottom is effected by means of Allen-Sherman-Hoff "hydrojet" slag tapping equipment. The slag is rejected from the wet bottom through an hydraulically operated water-cooled slag gate and spout. As it pours from the spout it drops into a water table formed by a high velocity water jet manifold. This high velocity water chills the slag and breaks it against a wearing plate located about two feet in front of the manifold discharge. After this disintegration of the slag, the water and slag mixture drops to a trench where it is picked up by a high velocity stream and sluiced to sizing grids located over a slag transfer sump. As it discharges to the sump it is picked up continuously by one of two slag removal pumps and discharged to an Ashcolite transport header which terminates at a 90-ton slag storage and dewatering silo located over a railroad siding. The ultimate disposal of the slag is to railroad cars.

Coals with ash fluid temperatures of 2100 to 2650 F have been tapped successfully from the furnace. It has been found necessary to have the boiler at ratings of about 300,000 lb per hr to start this operation, but after the slag is flowing freely the rating can be reduced to about 250,000 lb per hr and maintain satisfactory tapping conditions.

### *Fly Ash Removal*

United Conveyor equipment is employed to handle the fly ash from the boiler and the Cottrell electrostatic precipitator. Adequate vacuum is produced by a "Hydroveyor" for the transportation of fly ash from the precipitator and last pass boiler hoppers to a 25-ton storage tank which is in line with the slag storage tank and over a railroad siding. Disposal of the fly ash is to automotive dump trucks which haul it to various fills or dumps in and around the city.

Tests have indicated that from 50 to 60 per cent of the total coal ash is handled by the vacuum system and collected as fly ash. The slag recovered from the wet bottom varies from 50 to 40 per cent of the ash in the coal, depending upon the furnace temperatures and ratings maintained.

### *Coal Handling System*

Coal handling at this plant consists of transferring coal from railroad cars to station bunkers and to a 20,000-ton storage yard, or reclaiming coal from the storage and delivering it to the station bunkers.

A central unloading track hopper provides an unloading point for railroad cars. This hopper has a gravity discharge to an apron conveyor which deposits the coal on a conveyor belt terminating at the station bunkers or to a belt terminating at an unloading tower in the storage yard. A crescent power scoop on a drag scraper provides the means of removal of coal to the point of desired storage. A reclaiming hopper similar to the track hopper is located in the storage yard and provides the outlet from storage to the station bunkers.

The conveying system has a capacity of 150 tons per hour of slack bituminous coal and supplies coal to two bunkers, one having a capacity of 800 tons and located over the high-pressure part of the station, and one having a capacity of 2000 tons, located over the old boiler room. Some 2000 ft of 24-in. rubberized belting is employed in the conveyance of coal.

### *Feedwater Treatment*

Makeup water for the boiler plants originates from the Richmond city water mains and is zeolite softened before being supplied to the deaerating feedwater heater. Sulphate, phosphate and caustic solutions are injected into the mud drum of the high-pressure boiler by an intermittent operating high-pressure, displacement-type, chemical-feed tank. Electrical contacts on the boiler steam-flow meter establish the frequency of the chemical charge and an adjustable time-delay-operated thrustor valve establishes the quantity of the charge.

A continuous surface blowdown is operated to maintain the desired concentrations and a system of flash tanks and heat exchanger is employed to reclaim as much of the heat from the blow as possible.

The city water, of which the plant uses a 10 per cent makeup because of unreturned condensate from a steam sales system, contains some 10 to 12 ppm silica. It has been found desirable to limit this concentration in the boiler to 30 to 40 ppm. This limitation establishes the rate of blowdown.

### *Feedwater Heating*

Two direct-contact feedwater heaters serve the station boilers. The low-pressure deaerating heater is of Cochrane design and has a capacity of 600,000 lb per hr. Receiving condensate from the surface condensers and makeup water from the zeolite softener, it supplies the suction of four 250-lb feed pumps which serve the sixteen low-pressure boilers. These pumps also supply the suction for the high-pressure heater of the superposed extension. The latter, of Westinghouse design, is of the direct-contact type, receiving steam from the 200-lb header and water from the 250-lb feed pump discharge. It supplies the suction of the 1000-lb high-pressure boiler feed pump battery consisting of two steam-turbine-driven and two induction-motor-driven six-stage Ingersoll-Rand pumps. The performance is here given.

The steam-driven pumps are equipped with 555-hp non-condensing single-stage steam turbines. These turbines receive steam from the 900-lb header and exhaust at 200 lb to the main 200-lb header.

**PERFORMANCE OF PUMPS**

**At constant speed and 375 F suction**

| Lb per Hr | Total Dynamic Head | Efficiency Per Cent | Bhp |
|---|---|---|---|
| 416,000 | 1,900 | 72 | 553 |
| 350,000 | 2,100 | 72 | 512 |
| 260,000 | 2,290 | 66 | 455 |
| 175,000 | 2,380 | 55.5 | 378 |

**At constant total dynamic head, 2,100 ft**

| Lb per Hr | Rpm | Efficiency Per Cent | Bhp |
|---|---|---|---|
| 350,000 | 3,500 | 72 | 512 |
| 260,000 | 3,370 | 67.2 | 409 |
| 175,000 | 3,300 | 57.5 | 321 |

### *Annunciator System*

The boiler operating board is provided with an index-card drop-type annunciator and a bell alarm which signals the drop of any card. The annunciator provides warning of faulty operation of factors which can be of serious consequence, and yet not necessarily noticed by the operator. Some of the thirty faults causing annunciator operation are as follows:

1. Interruption of 2300- or 220-volt station service
2. Low coal in feeder hopper
3. Furnace and boiler draft intensity irregularities
4. Steam and preheated air temperatures too high
5. Fire failure in furnace
6. Boiler chemical feed out
7. High and low water in high-pressure heater
8. Precipitator out or smoke intensity high
9. Ash removal sump water high or low

The annunciator system has been very useful in normal operation and almost indispensable during preliminary operation.

### *Electric Eye*

An electric eye signals through the annunciator system a furnace puff out or fire failure in the combustion chamber. The eye is directed at the furnace flame through an observation hole in an inspection door at the operating floor level.

### *High-Pressure Turbine-Generator*

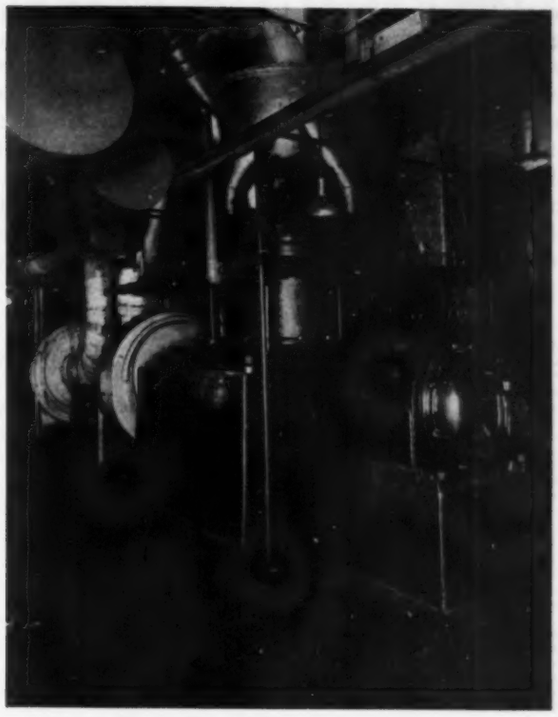
The high-pressure topping turbine is an eleven-stage GE 3600-rpm non-condensing machine designed to operate at an initial pressure of 850 lb gage and 835 F and to exhaust at 220 lb back pressure and 530 to 565 F, depending upon the load.

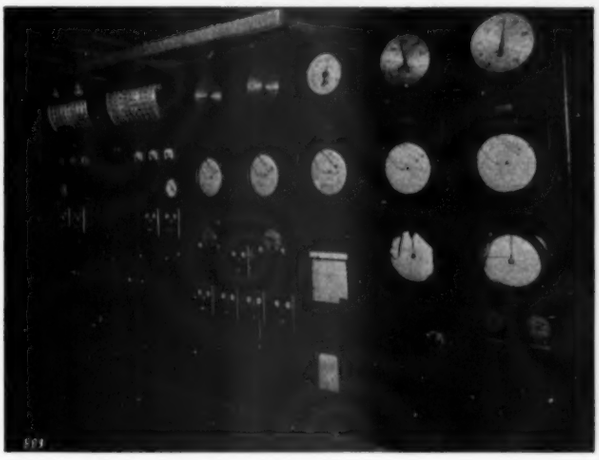
Five operating valves admit steam to the first- and second-stage nozzles of the turbine, four to the first stage and one to the second stage. Three of these valves are located on top of the unit and two are attached under the turbine and below the operating floor level.

The turbine is normally operated through the control of a back-pressure regulator which functions to position the steam admission valves in accordance with the demand on the 200-lb header. The complete controlling mechanism consists of an additional manual control for starting the turbine, a speed governor remotely controlled for synchronizing the generator, and safety tripping devices to protect the turbine against dangerous overspeed and failure of the lubricating oil supply.

The generator is a 15,000 kva, 13,200-volt, 3-phase machine with a direct-connected totally enclosed exciter. It is equipped with oil coolers, air coolers, oil filter and $CO_2$ release for fire protection.

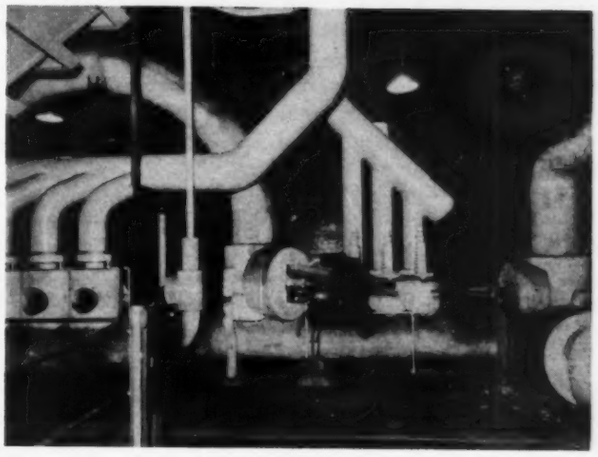
Right—View of pulverizers





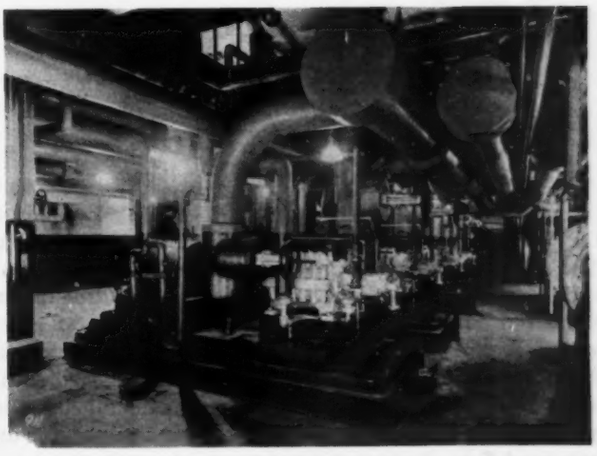
Above—Boiler control board

Right—High-pressure steam manifold



Below—High-pressure steam generating unit

Below—High-pressure boiler-feed pumps



The exhaust from the high-pressure turbine is under the control of a Foxboro temperature controller which regulates the supply of feedwater to a Smoot spray-type desuperheater in the 200-lb header. The characteristic steam temperature curves of the superheater outlet and the turbine exhaust are such that desuperheating is seldom necessary in normal operation. However, when the boiler is operated during an outage of the superposed turbine, it becomes necessary to pass the steam through a reducing valve which would result in an excessive temperature in the 200-lb header. The desuperheater under this phase of operation is very necessary for the protection of equipment, the steam temperature limit of which is 550 F.

TABLE 1—TEST RESULTS ON HIGH-PRESSURE STEAM GENERATING UNIT

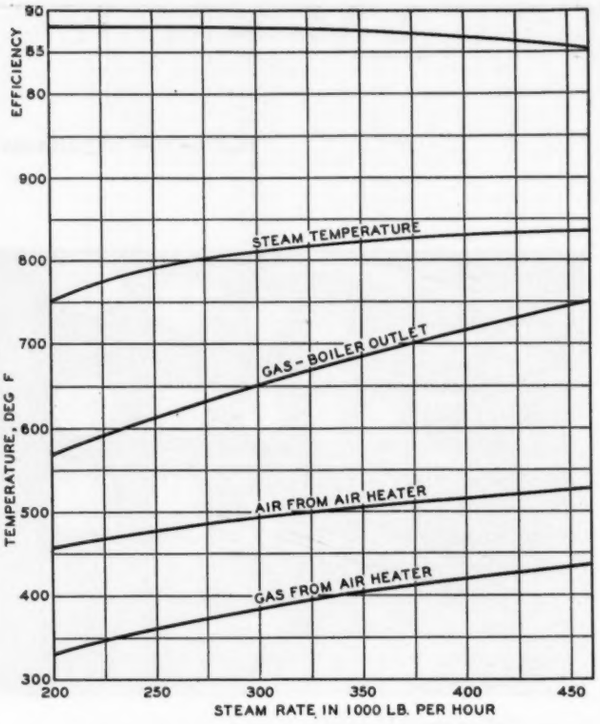
| Test number | 6 | 3 | 2 | 5 | 1 | 4 |
|---|---|---|---|---|---|---|
| Date | 7/15/37 | 7/10/37 | 7/10/37 | 7/14/37 | 7/9/37 | 7/12/37 |
| Duration—hours | 4 | 6 | 6 | 5½ | 6 | 2½ |
| Evaporation—lb per hr | 201,800 | 278,555 | 364,237 | 389,785 | 389,873 | 436,825 |
| Weighed coal—lb per hr | 16,281 | 22,680 | 30,820 | 33,110 | 32,428 | 36,824 |
| Steam temperature—°F | 753 | 808.5 | 824 | 820 | 832 | 824 |
| Water temperature—°F | 388 | 389 | 390 | 386 | 386 | 387 |
| Gas temperature—°F From air heater | 336 | 380 | 408 | 393 | 424 | 431 |
| Air temperatures—°F From air heater | 460 | 491 | 509.5 | 509 | 502 | 537 |
| Primary air-coal mixture | 138 | 140 | 142 | 132 | 137 | 143 |
| Pressures—lb per sq in. gage | | | | | | |
| Drum | 868 | 873 | 885 | 890 | 890 | 900 |
| Superheater header | 860 | 860 | 864 | 870 | 866 | 874 |
| Feedwater | 933 | 931 | 939 | 950 | 943 | 957 |
| Air pressure—in. water Primary air | 6.10 | 4.08 | 5.34 | 5.60 | 6.12 | 7.08 |
| Drafts—in. water | | | | | | |
| Furnace | .29 | .23 | .24 | .33 | .18 | .22 |
| Boiler outlet | 1.70 | 2.51 | 4.00 | 4.90 | 4.60 | 5.27 |
| From air heater | 3.10 | 4.88 | 8.19 | 9.45 | 9.59 | 11.40 |
| Flue gas analysis—per cent $CO_2$ | | | | | | |
| To boiler | 14.32 | 15.58 | 14.99 | 15.92 | 14.80 | 15.11 |
| Refuse analysis | | | | | | |
| Combustible — flue dust—per cent | ... | 8.51 | 9.64 | ... | 10.67 | 9.10 |
| H.H.V. flue dust—Btu per lb | ... | 600 | 820 | ... | 920 | 770 |
| Ultimate analysis—as received—per cent | | | | | | |
| Moisture | 3.28 | 2.59 | 3.69 | 3.28 | 3.50 | 1.97 |
| Carbon | 80.44 | 82.13 | 81.13 | 80.44 | 82.61 | 81.99 |
| Hydrogen | 4.45 | 4.40 | 4.24 | 4.45 | 3.93 | 4.56 |
| Nitrogen | 1.29 | 1.29 | 1.27 | 1.29 | 1.27 | 1.29 |
| Oxygen | 3.47 | 2.95 | 2.80 | 3.47 | 2.12 | 3.28 |
| Sulphur | .57 | .56 | .61 | .57 | .59 | .62 |
| Ash | 6.50 | 6.08 | 6.26 | 6.50 | 5.89 | 6.29 |
| H.H.V.—Btu per lb | 14,140 | 14,330 | 14,110 | 14,140 | 14,210 | 14,410 |
| Coal fineness—per cent | | | | | | |
| Through 200 mesh | ... | 79.55 | 73.85 | ... | 71.85 | ... |
| Through 100 mesh | ... | 94.85 | 92.85 | ... | 92.05 | ... |
| Through 60 mesh | ... | 98.60 | 97.35 | ... | 97.35 | ... |
| Through 40 mesh | ... | 99.75 | 99.45 | ... | 99.35 | ... |
| Heat balance—per cent | | | | | | |
| Dry gas loss | 7.14 | 7.69 | 8.40 | 7.91 | 8.90 | 9.62 |
| Hydrogen & moisture loss | 3.88 | 3.78 | 3.91 | 3.98 | 3.69 | 3.96 |
| Unburned carbon loss | 0.20 | 0.14 | 0.20 | 0.20 | 0.21 | 0.20 |
| Radiation loss | 0.85 | 0.60 | 0.50 | 0.45 | 0.45 | 0.40 |
| Total losses | 12.07 | 12.21 | 13.01 | 12.54 | 13.25 | 14.18 |
| Boiler efficiency | 87.93 | 87.79 | 86.99 | 87.46 | 86.75 | 85.82 |
| Boiler efficiency by weighed coal and metered steam and water | 88.07 | 88.87 | 88.13 | 87.12 | 89.13 | 86.23 |

### *Gravity Flow of Condensing Water*

The 12th Street steam plant is fortunately located on the James River at the site of the hydro development. The surface condensers are in the basement of the plant and are some 25 ft below the surface of the hydro station canal and 5 ft above the normal river water, or tail race, level. A circulating water gravity flow from the canal through the condensers to the river is accomplished without costly pumping. A booster pump is installed in the injection line of one of the 20,000-kw units to provide an increased flow of circulating water during extreme summer conditions but, due to the design of the condenser tube banking, this is seldom found necessary.

In cases of high river water which exerts a back pressure on the condensers and retards flow, the condenser discharge is emptied into a closed pit and pumped out to the river by four high water pumps.

In cases of low canal water, two pumps supply the condensers with hydro station tail-race water which is always plentiful.




**Curves showing test results**

### *Test Results*

The high-pressure steam generating unit was subjected to a series of tests at several ratings last summer, the results of which are given in Table 1 and the curves.

The rate of steaming was determined by steam and water meters and the coal fed to the mills was weighed on automatic scales.. Coal samples were taken at the conveyor belt feeding the automatic scales. Pulverized coal samples were taken at the mill outlet and fly ash samples at the Cottrell hopper discharge. The heat loss due to unburned carbon was determined by the calorimetric method. Data were taken largely from the operating instruments which had been previously checked and gas temperatures were measured by traversing with thermocouples.

The fuel burned was Pocahontas coal with an ash-fusion temperature of 2300 to 2425 F.

Table 2 shows the improvement in station economy since the addition of the topping unit.

TABLE 2—IMPROVEMENT IN STATION ECONOMY

| | 200-Lb Station | | 900-Lb Superimposed Station | |
|---|---|---|---|---|
| Season of year | Winter | Summer | Winter | Summer |
| Coal factor | 1.500 | 1.650 | 0.945 | 1.000 |
| Btu per net kwhr | 21,750 | 23,925 | 13,702 | 14,500 |
| Station efficiency—per cent | 15.7 | 14.3 | 24.9 | 23.5 |
| Station water rate | 14.5 | 16.0 | 10.8 | 11.4 |

# STEAM CONTAMINATION—III

## Determination of Steam Quality

By SHEPPARD T. POWELL
Consulting Chemical Engineer, Baltimore

**The third and concluding article of a series dealing with the causes, correction and measurement of steam contamination. The first, which appeared in the September issue, discussed priming and foaming and the effects of dissolved and suspended solids. The second article, in the October issue, described representative types of steam purification equipment. The present article deals with methods of obtaining a representative sample of steam and precautions to be observed in making a laboratory analysis, the determination of steam quality by the calorimeter and by electrical conductivity methods, the correction of errors due to dissolved gases, and the interpretation of conductivity measurements. The material in expanded form will appear later in the revision of the author's book, "Boiler Feedwater Purification"; hence, all republication rights are reserved.**

CONTAMINATION of steam with boiler water solids makes itself evident in the loss of efficiency of steam-driven prime movers, the accumulation of deposits in various parts of the steam cycle and drop in superheat of the steam leaving the boiler. While these difficulties may sometimes be corrected by careful operation, remedies in this field may not always be feasible, and steam purifying equipment of one type or another may be required. In order to guide boiler operation in a direction favorable to clean steam, and to evaluate the efficiency of steam purifying equipment, it is desirable to measure steam quality by some method that will give results rapidly and with the greatest possible accuracy.

At the outset it must be recognized that the ultimate criterion of steam quality is its favorable or adverse influence on operation, as indicated by difficulties of the types mentioned above. If steam contamination is responsible for fouling a turbine, then the data which will be most convincing to the plant engineer will be the daily capacity loss in kilowatts when a standard pressure differential is maintained across the turbine. The exigencies of plant operation, however, often make it difficult to obtain such data under conditions that are strictly comparable from one period to another. It may be found that a variety of factors have influenced the results in such a way that they cannot be used as a guide to boiler operation, or as indicating the efficiency of steam purification. Moreover, plant performance data of this kind do not furnish a promptly available and continuous record of steam quality that may be correlated immediately with various aspects of boiler operation. They are also incapable of demonstrating whether boilers or steam purifiers meet the manufacturer's guarantee in terms of total solids in the steam. It is therefore necessary to utilize some means of determining the moisture, or the entrained solid material, in samples of steam drawn from the system at appropriate points.

The procedure which will be chosen for determining steam quality in any specific case depends on the accuracy and the nature of the information desired and the conditions under which the test is made. The moisture makes itself apparent by a drop in the temperature of the superheated steam, which, for instance, at 400 lb pressure may be more than 13 deg F for each one per cent of moisture, as measured by the steam calorimeter. Tests may also be carried out directly by allowing the steam to impinge on a specimen turbine blade (1) and examining the blade for erosion or deposits after a specified period. As described in a recent issue of COMBUSTION (2), when moisture in steam exceeds 4.5 per cent it can actually be observed visually by scattered light if an intense beam from an arc lamp is directed along the axis of the flow. When it is desired to measure the solid matter, the steam must be condensed; its electrical conductivity may then be determined, or the residue on evaporation, if sufficiently large, may be weighed. A few other analytical procedures also have limited applicability to condensed steam.

### *Drawing a Representative Sample of Steam*

Impurities present in steam consist of fine droplets of boiler water (or feedwater if the steam is washed), which may lose moisture until the residue is a highly concentrated paste or a dry powder. Whatever the state of the contaminating particles, their density is greater than that of the steam, and because of the influences of gravity, centrifugal force, impact, or changes of velocity, they may not remain homogeneously distributed throughout the steam as it passes from the boiler to various parts of the cycle. It is therefore a matter of some difficulty to draw a sample of steam containing a quantity of contamination which will be representative of the total flow from the boiler.

The A.S.M.E. Power Test Codes, Part II, "Determination of Quality of Steam," (3) describes the standard steam sampling nozzle which has been adopted as most likely to draw a representative sample. This is a pipe

with a closed end, 1/4 or 3/8 in. inside diameter, and with a series of 1/8-in. holes drilled in a straight line, these holes facing the steam flow when the nozzle is in place. Cognizance is taken of the danger of uneven distribution of the contaminating particles, the Code specifying that, when possible, the nozzle should be inserted in a pipe in which the steam flow is vertically downward and as far removed from disturbing restrictions as possible. A sample from a vertical line with upward steam flow is stated to give high results for moisture, and, according to the Code, "The pipe bend and horizontal pipe should at all times be avoided, if an accurate determination of the quality of the steam is to be obtained."

It is often difficult to carry out these recommendations completely, as in the case of sampling steam delivered to the saturated header of a superheater by means of a number of tubes. For such samples a nozzle may be attached to each side of a tee located at a handhole plate on the header, or a pipe may be mounted on one end of the header, extending a convenient distance across it. Lateral variations in the circulation of the boiler or in the operation of steam purifying equipment may result in corresponding variations in the quality of the steam drawn from various sections of a superheater header, and it is necessary to establish experimentally the representative nature of the sample. Moreover, it would appear plausible that the rate of sampling should be great enough to permit the steam to enter the holes in the nozzle with the velocity at which it flows past the nozzle, although some evidence obtained by the writer indicates that this may not be necessary. It has been found, however, that when the apparatus for measurements on condensed steam is limited in size and can utilize only a portion of the sample that is drawn (as may be the case in conductivity studies), it is best to condense the entire sample and to draw off the desired portion as condensate instead of as steam. In separating a flow of steam into two fractions, it is difficult to effect a proportional division of the entrained contamination, and experiments have shown wide variations in results when this is attempted. The condenser should therefore be large enough to handle the entire quantity delivered by the sampling nozzle.

### *Contamination of Sample Must Be Avoided*

While the drawing of a representative steam sample requires a great deal of care, it is also necessary to avoid contamination after the sample leaves the nozzle. For calorimeter measurements the material of the nozzle and the sampling line is chosen mainly for the desired structural strength, but when the steam is condensed for conductivity measurements, it is possible that certain metals and other materials may influence the results. Copper tubing is frequently used to carry steam to the condenser, but this material should not be used where the temperature of the steam exceeds 406 F. Stainless steel tubing should be used at or above this temperature. Contamination is more apt to occur in the liquid phase, and to prevent this, block tin or tinned copper surfaces are probably best. On the other hand, there is considerable evidence that copper may be used satisfactorily and will reach a stable condition, after several days' operation, in which it will impart no measurable contamination to the condensate. Soldering flux or pipe compound may constitute a persistent source of contamination, and their use should be limited as much as possible. In general, however, a rapidly flowing stream of condensate will not attack ordinary resistant materials at a rate sufficient to influence conductivity readings.

The entire matter of representative sampling should be considered carefully in each specific installation of steam measuring equipment, and it must be established by experiment that homogeneous distribution of the impurities is maintained throughout, and that contamination from the measuring equipment is not occurring.

### *Steam Calorimetry*

The most familiar steam testing apparatus is the throttling calorimeter, a device into which steam is admitted through an orifice and allowed to expand to atmospheric pressure. Since the total heat of the steam is greater than the total heat of saturated steam at atmospheric pressure, the steam on the low-pressure side of the orifice will be superheated by absorbing the difference between these heat quantities. However, if moisture is present in the steam, part of the heat will be required to vaporize it, and the superheat temperature will be correspondingly lower. The difference between the theoretical and observed superheat is, therefore, proportional to the moisture in the steam. Radiation losses and thermometer inaccuracies must be determined by operating the boiler so as to assure 100 per cent dry steam and establishing the correction or "normal" of the apparatus. An accuracy of ± 0.2 per cent of moisture may be obtained with proper care.

This simplified description of the throttling calorimeter does not adequately cover the numerous types of steam calorimeters. For more complete details reference should be made to the A.S.M.E. Power Test Codes, which contain instructions for operating the recognized types of apparatus.

It should be noted that the possible error which the Code ascribes to the steam calorimeter, when applied to a carry-over of boiler water containing 2500 ppm of total solids, would correspond to 5 ppm of solids in the steam. In many cases, especially when testing the performance of steam purifiers, this precision may be inadequate. However, steam calorimetry is the best known and most widely practiced method for estimating steam quality, and will probably be favored whenever it is not definitely inapplicable.

### *Laboratory Analysis of Condensed Steam*

It is possible to evaporate a sample of condensate to dryness and weigh the residue of solids, as is regularly done with water from other sources. However, if a liter of condensate containing 1 ppm of total solids is evaporated in a dish weighing 15 grams, the increase in weight that must be measured is only one part in 15,000, and extreme care in evaporating and weighing is required to obtain satisfactory accuracy. If possible, a platinum evaporating dish should be used, since it is not easy to dry porcelain or glass dishes to constant weight within a sufficiently close limit. In the case cited above, 5 to 10 liters of the sample should be evaporated to obtain a larger residue, and it is obvious that special precautions should be taken to avoid contamination from the atmosphere. The apparatus shown in Fig. 1 has been developed for this purpose; its operation is apparent from the drawing.

The significance of all sources of error, and the elabo-

rateness of the precautions required, naturally decrease when the total solids in the condensate are larger in amount. On the whole, however, it is unwise to ascribe too great an accuracy to this procedure, and results should only be accepted after taking an average of two or more determinations.

Other laboratory procedures which are often applied to condensate are determinations of alkalinity, chloride, carbon dioxide, ammonia and pH. Little significance

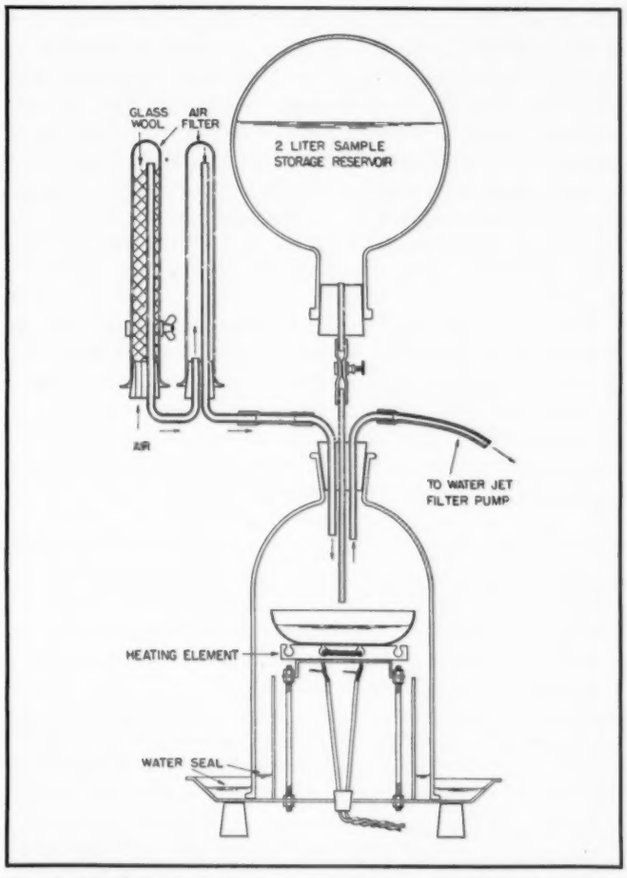



**Fig. 1—Apparatus for evaporating large samples of condensate while protected from atmospheric contamination**

can be attached to determinations of the methyl orange alkalinity of high grade condensate, and ordinary methods for chloride determinations are of no value. According to Kolthoff and Yutzy (4), the nephelometric procedure, based on producing an opalescence of silver chloride in a long column of liquid (such as in the Baylis turbidimeter), is accurate to within 2 per cent for as little as 0.8 ppm of chloride ion. Titrations for carbon dioxide, if carried out on steam which has not been treated to remove that constituent, and if protected from atmospheric contamination, may yield results of limited usefulness. The determination of ammonia is of special interest in connection with the measurement of electrical conductivity of condensed steam, and will be discussed under that heading.

Measurements of pH on condensed steam are of questionable significance because the sample is totally unbuffered and the hydrogen ion concentration may be greatly modified by the addition of an indicator, or even by the solution of glass from the glass electrode when the latter is used. It should be borne in mind that only 0.04 ppm of sodium hydroxide is required to raise the pH of pure water from 7.0 to 8.0. While the measured pH may fluctuate, depending on the condition of the steam with respect to the presence of alkaline salts, carbon dioxide and ammonia, it is impossible to arrive at the true pH because of the enormous effect of minor amounts of impurities.

### *Determination of Steam Quality by Electrical Conductivity Methods*

The soluble salts which are carried over from the boiler greatly increase the electrical conductivity of the condensed steam and this property furnishes a means of estimating the quantity of these contaminating materials. Such procedures for steam testing have been in use for at least ten years and have been used for detecting surface condenser leakage and in other applications for a much longer time. Hecht and McKinney (5) published an extensive description of conductivity measurements in 1931, and their paper includes a bibliography of earlier work.

The ohmic resistance of a sample of condensate may be measured, of course, by simply dipping two metal rods into the sample and connecting them in series with a sensitive ammeter or voltmeter and a source of current. The meter may be calibrated with samples of known concentration. Such assemblies are described by Tray (6) and by Ulmer (7), and have been used in some plants. However, when a current sufficient for these meters flows through an aqueous solution, a potential is set up at the electrodes and results in polarization. This opposes the externally applied potential and gives a false indication of higher ohmic resistance, i.e., lower salt concentration, than the solution actually possesses. These errors may be of serious consequence.

The most effective way to reduce polarization is to measure resistance with an alternating current of the lowest possible magnitude and the highest convenient frequency passing through the cell. This may be done with a properly designed Wheatstone bridge circuit for 60-cycle alternating current, in which the resistances of the various parts are so balanced that a very small current passes through the liquid. For steam testing the fixed resistances should be such that conductivities of the order of $10 \times 10^{-6}$ mhos may be read near the middle of the slide wire. Using a cell with a constant of 0.1 $cm^{-1}$, this makes the most accurate point $1 \times 10^{-6}$ mhos, corresponding to about 0.5 ppm. Conductivity meters of this type, with compensating dials for temperature and cell constant, are available; a more elaborate development is the fully automatic recording meter, interconnected with a temperature recorder and compensator.

The electrodes which are used for determining the conductivity of condensed steam should be inserted into a continuously flowing sample and should obviously be constructed of a highly-resistant material which will not be dissolved sufficiently to influence the results. Platinum and gold are satisfactory for this purpose, although for the less accurate ammeter methods monel or nickel rods have been used. Specific conductivity refers to parallel electrodes one square centimeter in area and one centimeter apart, but in practice the dimensions may vary. For use with solutions of extremely high resistance the spacing is conveniently made smaller and the observed results are multiplied by the cell constant, which

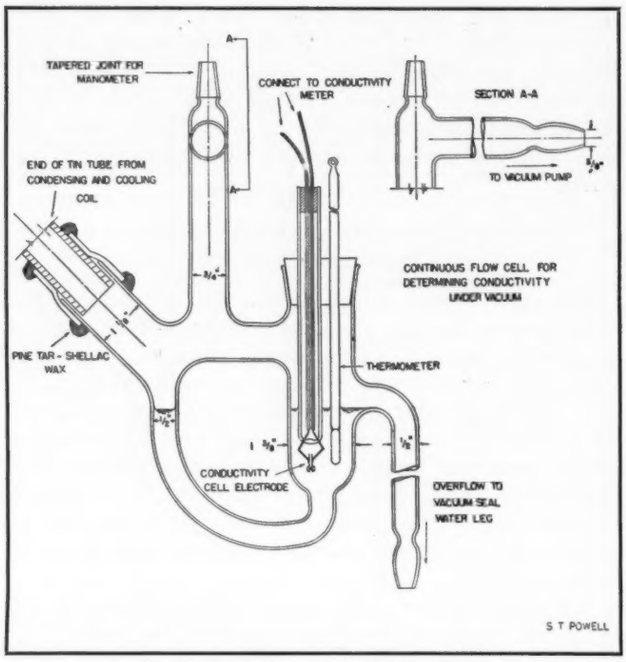

TAPERED JOINT FOR MANOMETER
CONNECT TO CONDUCTIVITY METER
SECTION A-A
TO VACUUM PUMP
END OF TIN TUBE FROM CONDENSING AND COOLING COIL
CONTINUOUS FLOW CELL FOR DETERMINING CONDUCTIVITY UNDER VACUUM
PINE TAR - SHELLAC WAX
THERMOMETER
CONDUCTIVITY CELL ELECTRODE
OVERFLOW TO VACUUM SEAL WATER LEG
S T POWELL

**Fig. 2—Conductivity cell mounted in continuous flow vessel**

is the actual separation of the plates, in centimeters, divided by the actual area of the plates in square centimeters. This constant is determined by calibrating the cell with a standard solution; 0.0001 normal potassium chloride, with a specific conductivity of $15.27 \times 10^{-6}$ mhos at 25 C (77 F), is satisfactory for this purpose.

Polarization may be reduced by using platinum electrodes covered with an electrically deposited layer of platinum, which has a velvety black appearance when properly applied. When the deposit becomes contaminated or marred, it is necessary to remove it, replace the electrodes[1] and redetermine the cell constant. Plain gold electrodes do not require as much attention and are satisfactory where polarization is greatly reduced by the use of a very small current. Fig. 2 shows a typical conductivity cell supported in a glass flow system. The thermometer, which should be near the electrodes, is read each time a measurement is made and the results are multiplied by the factors shown in Fig. 3 to correct them to standard (77 F). A resistance thermometer in a gold case may be used with manual or recording temperature bridges for readings at a remote point.

### *Correction of Errors Due to Dissolved Gases*

Steam contains appreciable concentrations of dissolved carbon dioxide derived from the decomposition of carbonates in the boiler water. When the steam is condensed this gas goes into solution as carbonic acid and may be stably held by converting carbonates to bicarbonates, which also causes the relative composition of the solids in the dissolved steam to deviate from those in the boiler water. Boiler feedwater often contains ammonia, either from chloramine treatment of the water supply, or from the decomposition of organic nitrogenous matter present in polluted waters. Although feedwater is highly alkaline and is usually deaerated at 212 F or higher, the ammonia may not be eliminated, and is released in the boiler and appears in the steam. Going into solution again in the condensate, possibly in combination with carbon dioxide as ammonium carbonate, it reenters the feedwater system and is recycled indefinitely. Even where a very small percentage of makeup is used, the writer has encountered 0.07 ppm of ammonia nitrogen in samples of condensed steam, and as much as 0.40 ppm has been observed in a high makeup plant. Since neither carbon dioxide nor ammonia represent entrained solids in the steam, but are highly conducting electrolytes when dissolved in water, their presence introduces a serious error into measurements of steam quality by conductivity methods. It is therefore necessary to eliminate these gases as effectively as possible and to make corrections for the residual amounts after determining them by chemical methods.

The first apparatus for degasifying a sample of condensed steam before measuring its electrical conductivity was designed by J. K. Rummel (8), and is based on flashing out dissolved gases at an elevated temperature. A modified form of this apparatus is shown in Fig. 4. The steam entering the apparatus is divided at a tee, part going through a "re-boiling" coil in the bottom of the degasifier chamber, and part passing through a condenser. The hot condensate is discharged into the degasifier chamber just above the steam coil which raises the temperature to the boiling point so that dissolved gases are flashed out of solution. These are vented out around the top of the chamber. Above the sample inlet is located a coil identical with the lower one, but carrying cooling water so that this section serves as a vent condenser. No steam should issue from the apparatus when it is properly adjusted. Part of the sample is discharged from the bottom of the degasifier through a heat exchanger which cools it, and then passes through an overflow vessel containing a conductivity cell and thermometer. An overflow on the sample inlet to the degasifier maintains the maximum water level just below the vent condenser coil,

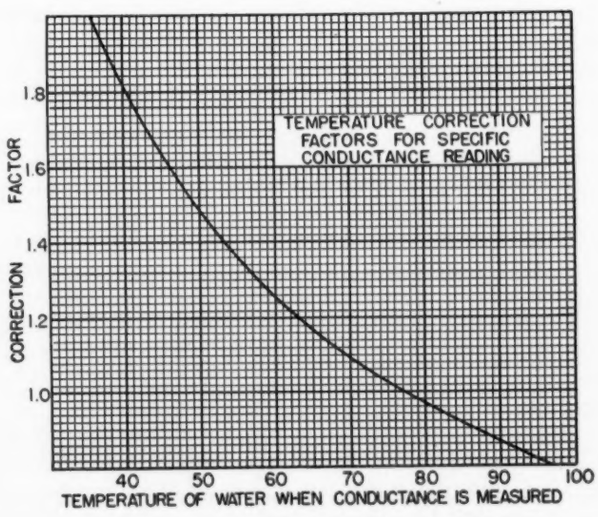



**Fig. 3—Temperature correction factors for specific conductivity measurements**

[1] Dip the electrodes in aqua regia (one volume concentrated nitric acid with three volumes concentrated hydrochloric acid), which will quickly remove the platinum black, and rinse them in distilled water; then immerse in a 3 per cent solution of platinic chloride containing 0.025 per cent neutral lead acetate, and connect the electrodes to one dry battery. Continue plating three minutes, reversing the polarity several times a minute. Rinse well in distilled water and wait 30 min for stabilization before determining the cell constant. Electrodes should be kept immersed in water at all times.

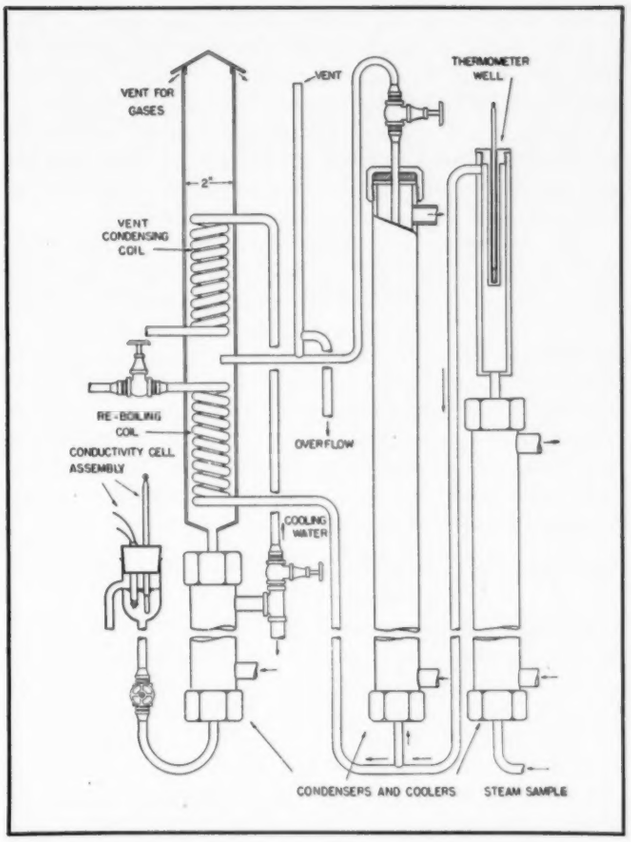



**Fig. 4—Modified degasifier and conductivity apparatus based on J. K. Rummel's design**

and by closing a valve in the overflow the apparatus can be flooded to wash the surfaces free of deposits.

A previous apparatus, in which the vent condenser was omitted, introduced positive errors, because sufficient steam escaped to concentrate the sample, and negative errors because this steam carried alkaline salts with it. The Rummel degasifier is capable of reducing the carbon dioxide content of steam to negligible amounts, but present experience indicates that it will not eliminate ammonia, although some reduction has been observed. The apparatus requires careful adjustment of the several rates of flow of steam and cooling water and, because of the difficulties inherent in maintaining a small, constant flow of high-pressure steam, it may not retain its adjustment over long periods without attention from the operators.

Several of these difficulties led to the development, at plants where steam testing was inaugurated under the writer's supervision, of procedures for drawing off soluble gases by means of a vacuum pump and measuring the conductivity of the sample while under vacuum. The earlier steps in this work have been described in a previous publication (9), and the essential elements of what is regarded as the most advanced design are shown in Figs. 5 and 6.

Calculation having established the quantity of steam that must be drawn to give a representative sample, the stainless steel tubing between the sampling nozzle and the condenser is made of such length and diameter as to deliver this rate of flow without throttling with a valve. The condenser is a coil of block tin tubing of $^3/_4$ in. inside diameter and should have sufficient surface to condense all of the steam and cool it to as constant as possible a temperature. With a water jacket consisting of an 8-in. pipe containing a central 4-in. pipe baffle to increase the velocity of the cooling water, a heat transfer coefficient of about 300 Btu per hr per sq ft per deg F has been observed. However, using a water jacket in the form of an outer coil of copper tubing of larger diameter, the higher velocities obtainable should yield a somewhat higher coefficient.

The condensed and cooled sample is delivered to a resistant glass flow vessel through which the condenser is connected to a vacuum pump. This reduces the pressure to several inches of mercury at the inlet end of the condenser, while at the lower end the vacuum gage should indicate only the vapor pressure of water at the temperature in the cell, non-condensible gases in measurable amounts being absent. In effect the steam is condensed and cooled in an atmosphere which is almost entirely free from ammonia and carbon dioxide and, except as these gases may combine to form ammonium carbonate in the sampling line or at the early stages of condensation, they should be entirely absent from the cooled liquid. Carbon dioxide may be reduced to negligible concentrations, but ammonium salts have been present persistently in investigations with which the writer has been in contact. To what extent ammonia may combine with acid constituents other than carbon dioxide in the steam is not known, and should be investigated.

The flow assembly which receives the condensate may be of any convenient form which provides an overflow and

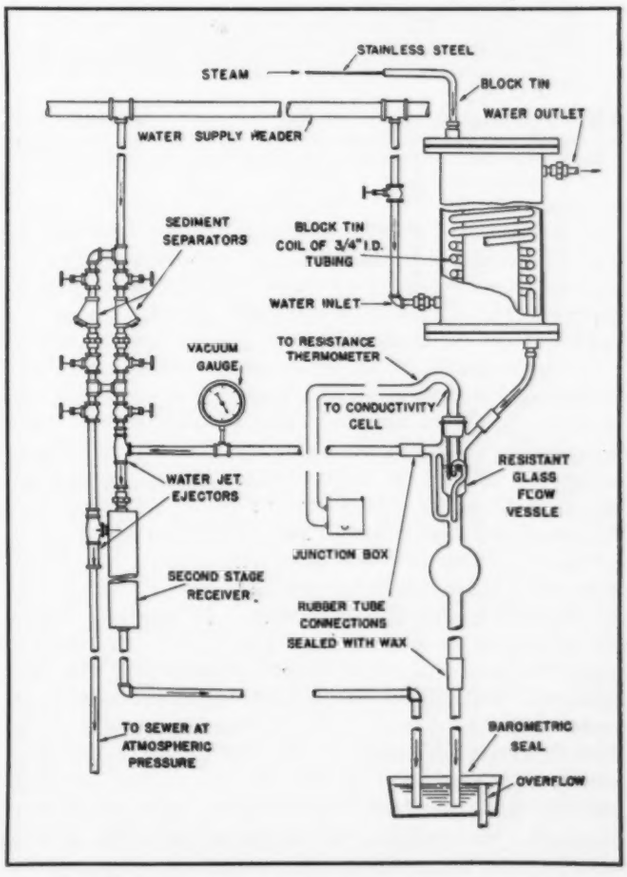



**Fig. 5—Apparatus for condensing steam and measuring conductivity under vacuum**

the necessary pressure-equalizing tubes, as shown in the two designs, Figs. 2 and 5. The liquid which overflows from the vessel should be discharged into a water leg constructed of copper tubing and leading to a seal at barometric height, i.e., about 35 ft, below the apparatus. Connections between the glass apparatus and metal parts are made with rubber tubing and all joints are made vacu-

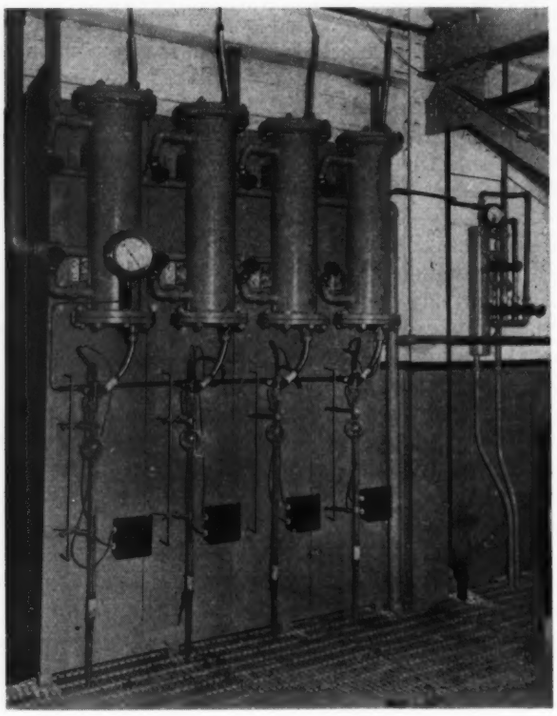


**Fig. 6—Sampling and testing conductivity equipment arranged for four boilers at Station 3 Extension of the Rochester Gas and Electric Corporation, Rochester, N. Y.**

um-tight with a sealing wax prepared by melting one part of black pine tar with four parts of flake shellac. A two-stage arrangement of high velocity water jets, as shown in Fig. 5, comprises a suitable vacuum pump, or a motor-driven oil-sealed laboratory pump may be used.

Samples should be drawn from the lower end of the water leg for determination of carbon dioxide and ammonia. A 250-ml sample, drawn by allowing the water to overflow a 500-ml flask for some time and quickly emptying off to an approximate 250-ml calibration, should not require more than two drops of N/50 sodium hydroxide solution to give a faint pink color with phenolphthalein. This is a very rough test, but it is believed that when these conditions are met, carbon dioxide may be regarded negligible. However, it is necessary to test for ammonia and, if positive results are obtained, to make frequent quantitative determinations of this constituent. The apparatus shown in Fig. 7 has been developed, under the writer's direction, for this purpose. The flow is passed through one of the Nessler tubes until steady conditions are anticipated, and is then directed through the other Nessler tube by changing the 3-way stopcock. One milliliter of Nessler reagent (10) is then added to the first tube by means of the screw clamp on the hose attached to the burette, and after ten minutes a comparison is made with permanent standards (10) in a rack which may be rested on the comparator. The operator looks in a horizontal direction at the mirrors underneath the tubes and observes as adjacent circles the light transmitted through the unknown and the standards. A permanent incandescent daylight lamp should be mounted at some height above the tubes. After making an observation the stopcock is reversed to flush out the first tube and the second sample is Nesslerized.

The correction to be applied to specific conductivity readings for ammonia found in the sample has been measured by Rummel and has also been calculated from the equivalent conductances of the separate ions. Since the form in which the ammonium ion is combined is not definitely known, this correction is somewhat ambiguous, being 7, 9 and 11 micromhos for one part per million of nitrogen in the form of ammonium sulphate, carbonate and hydroxide, respectively. Pending further investigation, a value of 9 micromhos per part per million of ammonia nitrogen is being used.

### *Interpretation of Specific Conductivity Measurements on Condensed Steam*

In making measurements of steam quality by conductivity procedures the operator determines the specific conductivity in micromhos of the liquid flowing through the cell; he simultaneously records the temperature and, by means of the factors given in Fig. 3, determines the specific conductivity at 77 F. Concurrently with these observations the sample leaving the apparatus should be Nesslerized, as described above, if it is necessary to make

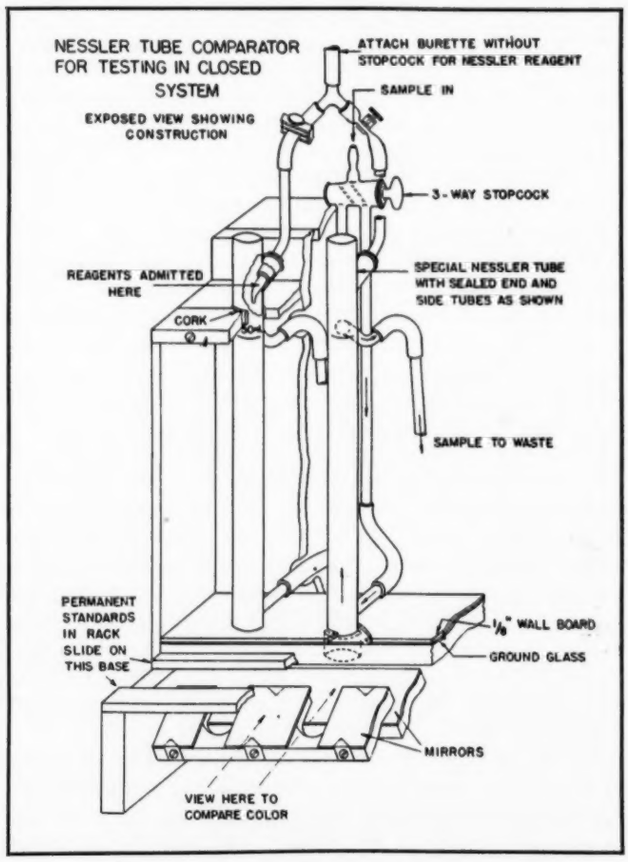

NESSLER TUBE COMPARATOR FOR TESTING IN CLOSED SYSTEM
EXPOSED VIEW SHOWING CONSTRUCTION
ATTACH BURETTE WITHOUT STOPCOCK FOR NESSLER REAGENT
SAMPLE IN
3-WAY STOPCOCK
REAGENTS ADMITTED HERE
CORK
SPECIAL NESSLER TUBE WITH SEALED END AND SIDE TUBES AS SHOWN
SAMPLE TO WASTE
PERMANENT STANDARDS IN RACK SLIDE ON THIS BASE
1/8" WALL BOARD
GROUND GLASS
MIRRORS
VIEW HERE TO COMPARE COLOR

**Fig. 7—Apparatus for determining ammonia in condensed steam in an enclosed system to prevent atmospheric contamination**

corrections for ammonia. Assuming that this is done, a deduction is made from the observed specific conductivity. The corrected conductivity thus obtained should be due entirely to soluble solids carried over from the boiler and it is necessary to establish an appropriate factor for converting specific conductivity, in micromhos, to soluble solids, in parts per million.

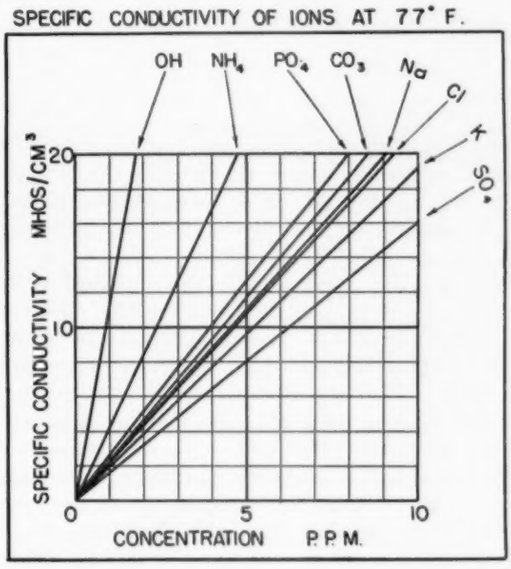



**Fig. 8—Specific conductivity of ions commonly found in boiler water as a function of their concentration**

Although the various ions in boiler water and feedwater differ considerably in their ability to conduct electricity through an aqueous solution, these differences are greatly reduced when the ions are compared on a weight-for-weight basis, rather than as ionic species, i.e., in terms of equivalents per liter. The specific conductivity of various ions as a function of concentration is shown in Fig. 8.[2] In boiler waters sodium is usually the only significant positive ion, and sulphate is the major negative ion, so that these two constituents are predominant in establishing the specific conductivity factor. Even in boiler water at a pH of 11 the concentration of the hydroxyl ion, which has a very high conductivity, is only 17 ppm and can only moderately affect the result. There is, as indicated, some difficulty due to the absorption of carbon dioxide by the more alkaline sodium salts, so that condensed steam contains bicarbonates which were obviously not present in boiler water.

In practice it has been found that a specific conductivity of one micromho corresponds to 0.5 to 0.6 ppm of soluble solids in the steam. This is based on extensive experiments, carried out at several plants, in which the condensate was contaminated with known amounts of solids in the form of boiler water and feedwater, and is confirmed by numerous weighings of the residue on evaporation of condensed steam. At each plant where conductivity methods are used it will probably be desired to establish this factor to the satisfaction of the operators. This may be done by fitting the stopper of a 2-liter flask with a conductivity cell, thermometer and burette. One liter of condensate is placed in the flask and is titrated with increments of boiler water of known concentration, added from the burette. The specific conductivity of the mixture is measured after each step in the titration and the increments of conductivity increase are plotted against the increments of concentration increase. The slope of the resulting line will give a factor which may be used for the purpose of converting micromhos to parts per million.

Together with the total solids in the steam obtained by applying this factor to the measurements described above a record should be made of the pertinent data concerning boiler operation. These may include the rate of steam generation, water level in the steam drum, temperature of superheated steam, concentration of the water in the boiler, and numerous other items that may be specified for the plant in question. When steam washers are in use the rate of flow of feedwater to the steam washer is significant. The assembly of such data in tabular and graphic form is of great value in correlating steam quality with various factors in plant operation.

[2] These values were calculated from the equivalent conductances of the ions at a series of specific concentrations, and not from the more familiar single values for "infinite dilution."


*Acknowledgments*

The art of measurement of steam quality by conductivity methods is a development to which a number of persons have contributed. Some of the earlier publications are set forth in the following bibliography. The most recent studies leading to modifications of Rummel's degasifier were carried out by T. E. Crossan and W. B. Gurney at the station of the Louisiana Steam Generating Corporation. Development of vacuum sampling technique under the writer's direction was inaugurated at the Paulsboro, N. J., refinery of the Socony-Vacuum Oil Company, Inc., by W. T. Sherman and W. A. Sibson. The apparatus was perfected as a permanent plant installation at the high-pressure station of the Rochester Gas and Electric Corporation by Irvin G. McChesney and Frank Henry. Credit is also due to members of the managing staffs of these firms for encouragement and suggestions, and to laboratory assistants who helped in the work.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# A.S.M.E. and A.I.M.E. Hold Joint Fuels Meeting

**Some high spots of papers presented at the joint meeting of the Fuels Division of the American Society of Mechanical Engineers and the Coal Division of the American Institute of Mining and Metallurgical Engineers at Pittsburgh, October 27 to 29. The papers in full will be obtainable from the respective societies.**

THREE hundred engineers, representing producers and users of coal, joined in a three-day conference at Pittsburgh on October 27 to 29. This was the first joint meeting of the Fuels Division of the A. S. M. E. and the Coal Division of the A. I. M. E. and it was the expressed opinion of those present that its success warranted future meetings of this character.

In addition to the technical program those in attendance at the banquet on Thursday evening listened to Charles Hosford, Chairman of the National Bituminous Coal Commission, discuss governmental regulation of the coal industry with particular reference to the engineering problems involved. Alex Bailey acted as toastmaster.

In all, fourteen papers were presented and the following abstracts pertain to those of particular interest to power engineers.

## Chain- or Traveling-Grate Stokers

Explaining the differences in construction details between the chain-grate and the traveling-grate stoker, Gosta Anbro, Superintendent of Power, Colgate-Palmolive-Peet Company, contradicted a widespread opinion that these differences have bearing upon their fields of application. While the traveling-grate stoker was developed primarily for burning small size anthracite and the chain-grate stoker to handle bituminous coals, we now find both types satisfactorily burning bituminous coal as well as anthracite.

A similar situation prevails with regard to the shape of furnace. While a majority of designers and operators believe that a bituminous coal furnace has to be shaped differently from one that is to burn anthracite, it was Mr. Anbro's opinion that the long rear-arch design is best adapted to both fuels. In support of this he cited identical furnaces that are in operation with anthracite and with bituminous coal and giving correspondingly good results.

The importance of the rear arch can best be appreciated by considering the particular operating problem that it solved. Burning out the fuel thoroughly is difficult, and with some coals impossible, without passing large volumes of excess air through the rear part of the fuel bed. If this air can be brought into combustion with the gases distilled off at the front, the furnace, as a whole, will operate with minimum excess air and combustible flue gas. This can be accomplished with any arch design by forcing air and gas together in a reasonably narrow throat and by providing temperature and time for complete combustion between the throat and the boiler tubes. The long front arch places the mixing over the coolest part of the grate, thus causing delayed combustion. With the front and rear arch design, mixing occurs over a hot zone when operating at or near capacity, but with a short fire the cold part of the grate extends under the point of mixing. The long rear arch insures good mixing over a hot zone under all conditions and also reduces the loss of solid carbon with the flue gas. While a skillful operator can obtain good results without the long rear arch one must realize that making operation easier and less dependent on skill is desirable.

The application of forced draft to both types of stokers was a milestone in their development by permitting the use of finer sizes of coal and greatly increasing the fuel-burning capacity. But forced draft increased the loss of carbon with the flue gases, as the high-velocity jets of air through the grate lifted small particles of coal from the fuel bed. Larger particles fall back and, in a front-arch furnace, land at the rear and are lost to the ashpit. With a rear arch they land at the front and repeat their travel with the fuel bed. They are also important for igniting anthracite in this type of furnace. Finer particles go up with the flue gas. For coals having a low ash-fusion temperature a considerable proportion will deposit on the first rows of boiler tubes and may constitute a slagging problem.

Mr. Anbro considered chain- and traveling-grate types as probably the most versatile of stokers with regard to fuel choice. Almost any solid fuel of suitable size, wood, peat, lignite, bituminous coal, anthracite and coke breeze, can be burned. However, definite limitations and preferences for efficient operation are found. No operator likes to handle strongly coking coals on a chain grate and particularly not those from the eastern slope of the Alleghenies. These coals need agitation of the fire bed.

These stokers seem to need a certain quantity of ash for protection of the grates, 6 per cent usually being set as the lower limit for bituminous coals. With anthracite there is no danger of getting near this limit. Ash with a high fusion point and minimum tendency to flux with refractories is desirable, but the importance of these characteristics depends on water-cooling arrangements

and shape and size of furnace. The coal, however, should be of fairly uniform size.

A. R. Mumford told of the experiences with traveling grate stokers at one of the plants of the New York Steam Corporation. Here, because of the high rates of burning and the necessity for keeping down cinder discharge from the stacks, the very small sizes have not been found most suitable. No. 3 buckwheat is burned with about ten per cent bituminous coal to aid ignition. Experiments with No. 4 buckwheat gave an efficiency of about 65 per cent at a burning rate of 25 lb per sq ft of grate; above or below this rate the efficiency fell off.

Otto de Lorenzi, of Combustion Engineering Company, expressed general agreement with Mr. Anbro and recalled that, although primarily designed for small sizes of anthracite, the traveling grate stoker was employed to burn midwestern bituminous coal as far back as 1919. With certain of these coals tempering with water has been found helpful. Forced draft was applied to the traveling grate in 1923 and to the chain grate in 1924. Lack of uniformity of size of the bituminous coal permits larger openings in the grate; hence the extensive use of the chain grate for such coals of the non-caking variety.

## Coal Selection for Underfeed Stokers

As an example of the benefits to be secured from careful selection of coal for underfeed stokers, J. E. Tobey, Manager, Fuel Engineering Division of Appalachian Coals, Inc., cited the experience of an industrial power plant in the Middle West burning approximately 700 tons per day. The boilers were initially laid out for hand firing but later changed to firing with underfeed stokers to secure increased capacity. The tube spacing which was correct for hand firing was inadequate for the increased volume of gas and, as a result, furnace pressures and temperatures were abnormally high.

When more units were added this mistake was repeated and the situation was further aggravated by greater height of the tube bank which increased the draft loss. In the third extension, consisting of four large bent-tube boilers, the tube spacing was correct but the baffle arrangement overtaxed the natural chimney draft and produced a bottling effect at high ratings. Also, the stokers were too long for the depth of the boilers and necessitated a retracted bridgewall under the mud drum. This did not prove satisfactory and was corrected by replacing the upper portion of the wall with a suspended arch section inclined toward the furnace.

Heavy loads imposed upon the plant necessitated operating the boilers at high capacities, which resulted in excessively hot furnaces, sometimes up to 3100 F, and created a serious fuel problem. Accordingly, steps were taken to improve operation by mechanical changes and an exhaustive coal-selection program.

No changes were made in the original boilers but their operating rates were reduced materially. Approximately 30 per cent of the heating surface of the second group of boilers was removed and this made possible an increase in steaming capacity. In the third group of boilers the original vertical baffling was replaced by a new design of cross baffle to reduce the draft loss; changes were made in the stokers to give better air distribution and control; and overfire air was provided.

At the time the coal-selection program was initiated coal was being purchased on a monthly spot basis with sixteen coal producers representing sixty mines on the approved list. This rendered segregation impossible and compelled burning the fuel as mixtures. In the three years during which the program was under way, coals from one hundred and thirty mines were analyzed and subjected to burning tests and those from eighteen mines, none among the original list of sixty, were found suitable. Differences as to quality, price, availability, etc., further reduced the number to six. These were subjected to trials for longer periods with the result that a single coal was finally selected and has since been burned exclusively.

Mr. Tobey related in detail the combustion troubles encountered during the tests with these numerous coals and expressed the opinion that many of the conditions met in this particular plant are to be found in hundreds of other plants, particularly those of small and medium size. He emphasized that this series of tests illustrates why a coal producer cannot supply some particular plant just because the analysis is satisfactory, and why those interested in market classification of coals must give great weight to the potential use value of the coal as well as its scientific value.

Maximum burning rate to which coal is subjected on any square foot of grate surface, rather than average burning rate per square foot of stoker area, is a determining factor in coal selection. The more freely a coal burns on a stoker the nearer the maximum burning rate for the most active square foot of grate area approaches the average burning rate for the whole stoker, and the smaller that ratio becomes the lower is the maximum temperature of the fuel bed. Making a caking coal burn more freely is equivalent to increasing the fusion temperature of its ash.

Stoker owners and manufacturers should work in closer harmony so that the latter may have full advantage of the varied experiences of the former, particularly with regard to the combustion behavior of various coals in underfeed burning equipment. This to the end that stokers will become more flexible, permit a wider coal selection range and not be affected by hairline differences in coals.

In discussing this paper, C. A. Reed, Secretary of Bituminous Coal Research, Inc., observed that while most stoker manufacturers state definitely what the equipment will do under given conditions, too often it is operated under conditions outside of the guarantees. Furthermore, as equipment becomes older it should not be called upon to carry overloads, but such is often the case.

## Selecting Coal for Pulverized Firing

"Contrary to the rather widely held impression that any kind of coal is suitable for pulverized firing, as much difference can be obtained between the use of a suitable and an unsuitable coal with pulverized-coal-firing equipment as with the average stoker. While pulverized-coal firing can probably be adapted to burn successfully any coal mined, if the installation is designed to handle one specific type of coal, other coals will give trouble."

With these introductory remarks, B. E. Tate, Chief Engineer of the National Cash Register Company, pro-

ceeded to outline the characteristics that must be considered in selecting a coal for such use. These are, use value, heat content, grindability, volatile content, moisture content, ash-fusion temperature, ash content, size of coal, foreign material and fly ash characteristics.

"Use value" Mr. Tate defined as the value of a coal when considering its effect, not upon the cost per thousand pounds of steam produced, but upon the entire plant operating cost.

While the heat content of a coal can be translated into monetary value, its effect on use value may be greatly magnified. Although the heat content of coals varies widely this is not due entirely to ash and moisture as oxygen and hydrogen exert an important influence. However, the heat content of coal from any particular seam, on an ash- and moisture-free basis, is remarkably uniform and seldom varies more than 100 Btu above or below the average from that seam. The speaker called attention to a practice among some coal dealers of giving the proximate analysis on the "as received" basis but listing the heat content on the "dry" basis without so designating it. This raises the stated heat value by several hundred Btu.

The effect of grindability on mill capacity or on fineness of pulverization is important. It bears on the cost of pulverization because less power is required to grind a friable coal, and there is less wear on the mill for a given degree of fineness. The life of a set of wearing parts when grinding a friable coal may be as much as three times that when handling a hard coal.

*Effect of Volatile Matter*

Volatile content must receive consideration because low-volatile coals require certain features of furnace design not necessary with high-volatile coals. The former are generally more friable and easier to pulverize but this advantage may be offset by poorer ignition and slower burning. If a furnace has been designed to burn high-volatile coal, low-volatile coal will have insufficient time for complete combustion and excessive carbon loss may result. Large furnace volume, preheated primary or secondary air, or both, restricted volume of the primary air and high furnace temperature are necessary features in burning low-volatile coal. While these features are also desirable in burning high-volatile coals, the latter will often give satisfaction when the former will not.

Coal containing excessive moisture will often be troublesome, through difficulty in unloading, clogging in the transport piping and causing momentary stoppage of the mill output with resulting loss of flame. Also, slower ignition encountered with wet coal may result in extended flame length and consequent impingement upon water-wall tubes. Such difficulties, however, may be avoided or minimized by proper plant design. Drying before pulverizing or supplying the mills with preheated primary air are very effective in overcoming grinding and burning difficulties, while preheated secondary air is a material aid in burning moist coal.

Ash-fusion temperature is important and should be above or, for slag-tap furnaces, below a definite figure. Low ash-fusion coal may, through slagging the boiler tubes, start a progressive cycle of conditions that will prevent a boiler from carrying its required load for a week. A vicious cycle may be set up through the slagging of the tubes, causing restricted air flow which produces high $CO_2$ with accompanying increased furnace temperature. This furthers the slagging and raises the furnace temperature still higher. With a dry-bottom furnace very high ash-fusion temperature is not necessarily most desirable, for coal having a borderline ash-fusion temperature may result in a porous sandlike deposit on refractory walls which is often desirable to protect them and reduce air infiltration. Such a condition may be had without encountering difficulties from slagged tubes.

The speaker cautioned care in mixing coals for pulverized firing and cited tests showing that when a coal of 2485 F ash-fusion temperature was mixed with an equal amount of 2705-F coal the resulting mixture had an ash-fusion temperature of 2284 F.

Size of coal is another important consideration, for a material increase in either pulverizer capacity or fineness may be expected when substituting $^1/_2$- or $^3/_4$-in. slack for 2-in. nut and slack from the same seam. However, while smaller size coal usually offers an advantage in price this may be offset by higher ash content and lower calorific value. Objections sometimes raised against the use of small sizes are increased handling costs from cars, the liability to accumulate more surface moisture in transit or storage and more dust, although coal producers are now taking steps to minimize these objections.

## Coal Selection

"The Status of Our Knowledge of Coal Selection for Steam-Generating Equipment" was the subject of a paper by R. A. Sherman, Fuel Engineer of Battelle Memorial Institute. This was, in a sense, a summary of points brought out by the preceding A. S. M. E. papers on coal selection for different types of firing equipment, together with a review of current data and research on the subject of coal selection.

That the problem of coal selection is complex, because of the numerous equipment factors and coal characteristics involved, is borne out not only by the papers presented but also by published association data. For instance, in the charts issued by the Committee on Coal of the National Association of Purchasing Agents the characteristics of coal for steam generation are listed under thirty-two items, each of which must be considered with relation to the factors of equipment and type of installation which in some cases number as many as nine. Furthermore, the American Society for Testing Materials has twelve Standards and four Tentative Standards for methods of testing coal.

Few users have the necessary knowledge of how best to select coal for their particular requirements nor a clear-cut analysis of the condition and demands of their equipment; the coal producer either lacks or suppresses this information in his enthusiasm to obtain orders; and failure of the equipment manufacturer to pass along this knowledge to the customer indicates lack of such knowledge.

Among the points stressed by Mr. Sherman were:

1. That of the three principal requirements of coal, namely, dependability, economy and cleanliness, the first is the most important; for often the coal that is most economical as to price, cost of preparation and efficiency,

when measured on the basis of cost per thousand pounds of steam, may not be the one to use because it will not carry the load.

2. Authoritative data on the effect of size of coal on its performance on large stokers are lacking although research at Battelle Memorial Institute has produced data dealing with the effect of coal size on the performance of small underfeed stokers.

3. Because of the importance of coking characteristics and their variability among seams and coals of different sizes from the same seam, it is unfortunate that no definite method of measurement exists.

4. While the general relation of volatile matter to rate of burning of pulverized coal is fairly well established, differences exist in the rates of burning of coals having similar volatile contents and little is known of this characteristic.

5. Rate of burning must be considered together with the factor of grindability, and low-volatile coals, which must be more finely pulverized than those of high volatile, are softer or have a higher grindability index. That softer coals do require a longer burning time is often overlooked and grindability is therefore sometimes accorded greater importance by producer and user than is warranted.

While much still remains to be learned about coal, Mr. Sherman felt that available knowledge is not being used to the fullest extent, not only by the small plants but by many large plants as well. This is perhaps due to the fact that available knowledge is so widely scattered. To assist in correcting this situation the A.S.T.M. is preparing to publish a book comprising a symposium on the significance of tests of coal together with the discussion on coal presented at its last annual meeting.

While the process of education is going on to promote intelligent use of existing information, research on the unknown factors is being continued by several universities, the Bureau of Mines, private institutions, coal users, equipment manufacturers and coal producers. Mr. Sherman then outlined the organization and program of the Bituminous Coal Research, Inc., and expressed the hope that ultimately research would lead to the design of equipment that would not be so particular as to the characteristics of the coal burned.

## Interpretation of Laboratory Coal Tests and Sampling Methods

The paper by G. B. Gould, President of the Fuel Engineering Company of New York, discussed the accuracy with which one test indicates the quality of one lot of coal and the accuracy with which a test of one lot of coal represents the average quality of a commercial product of which the buyer will presumably receive many shipments. Even were it possible to determine with absolute accuracy the quality of one lot of a coal, this would indicate only the average quality to be expected from a series of shipments of that coal, within the limits of variation that are characteristic of that coal.

The extent of deviations in quality of one lot of a coal from the average of a number of shipments is traceable to such factors as percentage of ash, size, ratio of free impurities to total impurities, nature of free impurities, methods of mining, loading and preparation, and shipments from two or more mines as a single product. Mr. Gould then discussed the probable errors involved and the application of tolerances to commercial practice.

With reference to steam plant trials of a coal, he stated that these, while having value, do not provide a substitute for the laboratory tests, although either is necessary for interpretation of the other. Actual trials of coals provide an opportunity to observe the physical effect on the fuel bed of size and coking properties, and to clear up those fringes of doubt, which will always be present, as to the combined effect of all of a coal's properties, under a particular combination of plant conditions. Employed with technical discretion, and in combination with laboratory tests, such trials constitute the final refinement in coal selection.

Frequently, however, the relative values of coals are judged solely by comparative evaporation figures, not uncommonly from tests of only a few hours' duration. Aside from the fact that in most plants measurements of coal and water or steam are much less accurate than laboratory measurements of coal quality, there are numerous variables in a steam plant, which affect the evaporation from one period to another, and have no relation to the properties of the coal in use. These include the load and its variations, the cleanliness of boiler surfaces, regulation of the air supply and the habits of individual firemen. Sometimes a test of this kind is made with one coal under careful supervision and the results are compared with records of performance with another coal under ordinary, unsupervised operation.

It has already been pointed out that any one shipment of a coal is not a reliable indication of its average quality. Therefore, comparisons of value based on evaporation figures resulting from individual trial purchases have no greater accuracy at best than a single laboratory test of any one lot of coal and need to be adjusted to the average quality of the coal, determined by laboratory tests of a series of samples.

Practical trials, standing by themselves and unrelated to the chemical and physical properties of the coals as revealed by the laboratory, severely limit the number of coals that can be considered with discrimination, and supply experience that is of little value in judging of some other coal in advance of a similar trial.

### *Penalty and Premium Contracts*

In conclusion, Mr. Gould offered the following observations with reference to penalty and premium contracts:

"Buyers do not always realize that when only penalties are provided the practical effect is to set an average standard of quality that is very much higher, if all of the deliveries are to escape a penalty. There are cases where the buyer, using specifications of this kind, has quite unconsciously established in effect an average quality higher than any available coal. Or, in other words, any available coal will incur a penalty some part of the time.

"It is not uncommon for penalty and premium contracts to provide for price adjustments based on small variations that are, in fact, well within the probable error for the kind of coal being purchased. If the mathematical principles that govern variations in coal quality were applied, it would be seen that these smaller variations compensate for each other, and the operation of the specifications could be simplified.

"Penalty and premium contracts should be drafted with

a clear understanding as to whether intention is to adjust for differences in average quality, or to set limits, or to combine the two purposes."

## Segregation in Handling of Coal

David R. Mitchell, Assistant Professor of Mining and Metallurgical Engineering at the University of Illinois, dealt with segregation in the handling of coal. He showed that segregation may be of two kinds, namely, "size segregation" in which particles of the same size in a mass of coal containing a range of sizes collect together, and "density segregation" in which particles of the same density or specific gravity collect together. The former cannot take place with closely sized coal, and cleaned coal with particles of approximately the same specific gravity has very little tendency for density segregation.

In this connection reference was made to tests at the University of Illinois power plant where the bunkers were filled with $1^1/_4$- or $1^1/_2$-in. raw screenings by means of a Peck carrier dumping at one side of the bunker. A cone of fines was built up along one side which gradually graded to nut on the opposite side. Somewhat similar tests using a small circular bin in which care was taken in filling to avoid segregation showed that resegregation upon withdrawal was negligible.

Segregation on belt and bucket conveyors takes place when the conveyors are loaded from the side by a chute. In this case both size and density segregation take place, the refuse particles of high specific gravity tending to segregate with the fines. Also, segregation takes place on flight conveyors, from front to back, of the coal being dragged along by the flights, and on pan or apron conveyors from top to bottom, the fines sifting through the coarse particles to the bottom. In spiral, screw or worm conveyors the fines collect along the bottom of the tube.

### *Sampling Affected by Segregation*

Most of the erratic results of sampling can be traced to segregation of coal on conveyors, in railroad cars, in trucks, storage piles or bins. Sampling methods or devices that take part of a moving stream of coal all or part of the time are to be looked upon with suspicion. At the point of consumption, segregation of fines, of coal constituents, of impurities, etc., all taking place simultaneously, may nullify all the efforts of the coal-preparation engineer to produce a clean, uniform and otherwise well prepared product.

In chain-grate stoker operation, irregular feed of coarse and small coal causes a spotty fire with blow-holes, and if excess fines occur at certain periods during the day a great reduction occurs in capacity, which is often far more important than reduction in efficiency.

In an underfeed stoker, segregation of fines upsets the air distribution, as in the chain grate, and causes holes, matting, clinkering and, for some types of coals, excessive coking of the fuel bed.

Lastly, segregation in bins, bunkers and storage piles increases the tendency for spontaneous combustion.

The condition on the surface of the particles has a marked effect on the angle at which particles will begin to slide, and also the angle at which they continue to slide. Also the relative fusibility and slacking properties influence segregation.

Tests at the University of Illinois to determine the angle of repose of different sizes of an eastern Illinois coal showed that the decrease in the angle of repose of the extremely small sizes, as compared with the larger sizes, is marked and is contrary to the generally accepted theory that segregation is due largely to differences in the angle of repose of the various sizes.

It seems likely, then, that size segregation occurs largely because of differences in rolling friction, differences in shape and differences in the force and momentum at which the various sizes hit the pile.

To reduce segregation, conveyors should not be fed at right angles to but in the direction of travel. Belt conveyors are frequently loaded with fines first and the coarser particles on top. This may not have a bad effect if proper discharge arrangements are provided, but because of differences in the trajectory at the point of discharge, a bad case of segregation may result from this practice. Vibrating conveyors move the material in such a manner that little, if any, segregation takes place.

The extent to which segregation may take place on feeders, particularly of the chute type, is not generally recognized. Segregation with flat chutes is very noticeable. Better results are obtained with a fan or fishtail chute as used to feed stoker hoppers where deflectors are employed to obtain an even distribution of the coal across the discharge of the chute, particularly as to size distribution.

One of the latest developments for reducing segregation at stoker hoppers is the conical distributor.

## The Chemical Treatment of Coal and Coke

Attempts to improve the burning of coal by pretreatment with chemicals dates back to the early years of the last century, according to P. Nicholls, Supervisory Fuel Engineer of the U. S. Bureau of Mines. Many of these proprietary products have been marketed as "fuel savers" when used in the quantity of up to 4 lb per ton of coal, but numerous tests of such products at the Bureau in 1910, 1916 and 1930 definitely disproved the claims of the vendors as to the saving of fuel, elimination of smoke and soot deposits, and reduction of clinkering. Some of the constituents of these products when used in larger quantities, of 20 to 40 lb per ton, did show some favorable effects on the condition of the fuel bed with certain coals, but in the recommended quantities up to 4 lb per ton little material effect was noticeable.

Although not claimed in the literature on various chemical treatments, it was found that certain substances, notably sodium carbonate, possessed the power to reduce caking to some extent, particularly with weekly caking coals from the Middle West. However, with a strongly caking Eastern coal, such as from the Pittsburgh fields, there was little, if any, effect. The ability of treatments to reduce caking decreased with decrease in thickness of the fuel bed and with an increase in the rate of air supply. Boric acid, molybdenum oxide and calcium chloride ranked next and treatment with water alone was found effective with coals that would absorb moisture.

There were no indications that the chemicals influenced the expulsion of volatile matter or that any increase in the rate of burning was associated with direct action between the chemical and the hydrocarbons. The activating effect of 4 lb per ton was small even with sodium carbonate under the most favorable conditions, but with 40 lb per ton sodium carbonate had the greatest activating power of the less expensive chemicals. Of the more expensive chemicals, copper chromate, potassium chromate and molybdenum were about on a par with it.

### *Shielding Effect of Chemical Treatments*

The ignitibility of a coal is shown by the rate of pick-up of the freshly fired fuel rather than by the temperature at which it starts to burn. The rate of pick-up is a composite of the ease of initial ignition and the reactivity of the fuel at low temperature and the ignition depends largely on the ease with which combustible gases are evolved. A chemical that increases the reactivity of carbon will also lower the temperature at which it will ignite, but if the chemical is applied to the outside of the pieces it will shield the carbon from the heat and thus retard the rate of pick-up. In most cases of chemical treatment the shielding effect was greater than the activating, so that pick-up was delayed, especially with the heavy treatments. The effect of the chemicals on ignition was greater with underfeed burning because the fuel is fed into a low-temperature zone, whereas in overfeed firing it is fed into a hot zone.

No treatment positively decreased the quantity of tar and soot in the stack gases, and neither light nor heavy treatments decreased the maximum density of the smoke or the total quantity.

Because the smoke was not decreased by the treatments, the tendency to deposit soot was not less, but when certain chemicals were employed, such as salts of copper and lead, there was a tendency for these deposits to be burned more readily.

None of the chemical compounds improved the nature of clinkering, but with heavy treatments up to 40 lb per ton the quantity of clinker was increased and the slag was more thoroughly fused where the addition of the chemical lowered the ash fusion temperature. No improvement resulted from the use of chemicals that increased the fusion temperature.

The amount of sulphur retained in the ashes and slags was small in all tests and the chemical treatments made no material change.

### *Conclusions*

Chain grates are widely used for burning weak and medium caking coals. The caking of coal on a chain grate tends to break the bed into isolated lumps of coke, which are likely to pass to the end of travel not completely burned. Hence a treatment that reduces the tendency to cake may be beneficial in such cases although the tests indicated that this result may be attained by wetting the coal with water before firing.

If any treatment other than water is to be used, the investigations have shown that sodium carbonate (soda ash) produces the greatest effect on the burning of both cokes and coals. Calcium chloride, while less effective in this respect, does decrease the dustiness of the fuel.

## Creep Test Data

The use of Least Squares for analyzing the data obtained in creep tests has been found to eliminate "the personal error involved in graphical analysis," according to information disclosed by research physicists of the United States Steel Corporation in a paper presented before the American Society for Metals at Atlantic City, October 20, 1937.

In this research, tests were made on specimens of carbon-molybdenum steel and carbon-molybdenum-silicon steel of 0.505 in. diameter by 2.3 in. All the tests on the carbon molybdenum specimens were made at 1100 F, after seven different preliminary heat treatments which yielded different initial structures, at varying stresses for a period of 3000 hr. The carbon-molybdenum-silicon specimens were tested at temperatures of 850, 950 and 1100 F, at varying tensions and with preliminary heat treatments.

Within the time and temperature ranges investigated, successively higher stresses tend to produce first a decreasing, then a constant and finally an increasing creep rate.

The authors say that "the present creep tests do not permit us to state definitely whether the changes evident in the final as compared with the initial microstructure of the specimens are due mainly to the influence of time at temperature or in part to the influence of stress. According to present indications, the influence of stress is secondary; but in order to determine this point, specimens of this steel variously pretreated are now being held for 3000 hr at 1100 F under stress."

Both the linear and the parabolic creep rate were calculated for each specimen. When these rates were plotted against the respective stresses, a set of curves was derived which showed a divergence between the two calculations.

"Of the seven heat treatments investigated, the maximum creep resistance over the 3000-hr test period was developed by the preliminary treatment of tempering the normalized steel for 4 hr at 1300 F, which produced a fine ground-mass precipitate, probably a molybdenum-rich carbide.

"The stability of this precipitate probably accounts for its lasting ability to improve the creep resistance of the alloy. The structure produced maintained a constant (linear) creep rate at higher stresses than did the structures resulting from other treatments, and the tendency to an increasing (accelerated) creep rate at higher stresses seemed to be least for this treatment and maximum for those specimens showing the greatest changes in microstructure during the creep test. The behavior of the precipitate as demonstrated by the changes in microstructure offers a tangible reason for the improvement in creep resistance imparted to steel by the addition of molybdenum.

"Creep tests on a normalized and tempered chrome-molybdenum-silicon steel indicated that a stress of 28,500 lb per sq in. was required for a creep rate of 0.13 millionths inch per inch of length per hour at a temperature of 850 F. At 950 and 1100 F stresses of 19,750 and 6250 lb per sq in. were required for a creep rate of 1.0 millionths inch per inch per hr. Annealed chrome-molybdenum-silicon steel was found to possess slightly greater creep resistance at 1100 F than the same material which had been normalized and tempered."

# The Flow of WATER and COMPRESSED AIR in Pipes

By F. M. VAN DEVENTER
Assistant Chief Engineer,
Walworth Company, Inc.

IN the October issue of COMBUSTION there appeared an article by the writer, in which the selection of optimum pipe size for the transmission of any fluid was indicated to be a problem in economics. The proper analytical attack was outlined, and it was shown that the friction loss or pressure drop of the fluid in the pipe is the principal determinant. The article embraced also a chart and simplified formula for the flow of steam in pipes, to assist the designer in the determination of the flow loss in the transmission of that fluid.

The present article presents supplementary charts and formulas for the flow of water and compressed air.

### *The Flow of Water*

PROBLEM:

Water at the rate of 260 gpm flows through a 5-in. standard weight pipe. What is the pressure drop due to friction and what is the velocity head due to flow?

SOLUTION by CHART:

A horizontal line representing 260 gpm and a diagonal line representing a 5-in. pipe establish a point of intersection. From this point a vertical line to the lower scale shows the friction loss to be about 15 ft of water or 6.2 lb per sq in. per 1000 ft of pipe. A diagonal from the point of intersection to the lower right quadrant of the chart shows the velocity to be 4 ft per sec, and the velocity head 0.25 ft of water.

Four quantities are involved in the use of the chart, namely, the rate of flow, pipe size, friction and velocity. Any two of these four data establish a point of intersection from which the two other quantities are indicated.

SOLUTION by FORMULA:

The chart is based upon a slight modification of the Saph and Schoder formula, which is usually given as:

$h = 0.38 \times \frac{v^{1.86}}{D^{1.25}}$, where $h$ is the friction loss in feet of water per 1000 ft of pipe, $v$ is velocity in feet per second and $D$ is the internal diameter of the pipe in *feet*. Since it is usually more convenient to work with diameter in inches, and since velocity can readily be expressed in terms of cubic feet per second and diameter, the author suggests as a more convenient form, the following modification of the original formula:

$h = (cfs)^{1.86} \times F$, where $h$ = head loss due to friction in feet of water per 1000 ft of pipe, $cfs$ is cubic feet per second of water flowing and $F$ is a factor which is a function of the inside diameter, with which the formula constant is combined. Its value is $\frac{147{,}300}{d^5}$. Velocity in feet per second is determined from the formula:

$fps = 183.2 \times \frac{cfs}{d^2}$, and velocity head: $\frac{(fps)^2}{64.4}$.

For convenience in the use of the formula, values of $F$ for nominal pipe sizes are tabulated in Column 2 of the accompanying table.

The friction of water and similar liquids may be greatly influenced by the condition of the wetted inside surface of the pipe. Thus, rough cast iron or tuberculated steel offers more resistance than a clean, smooth pipe.

The chart and formula as given represent new, smooth pipe surfaces. Small sizes of pipe, after serious corrosion or tuberculation may impose frictional head losses five

NUMERICAL VALUES OF FACTOR "F"

| Nominal Pipe Size | Water: Standard Weight Pipe | Compressed Air: Standard Weight Pipe | Compressed Air: Extra Strong Pipe |
|---|---|---|---|
| Col. 1 | Col. 2 | Col. 3 | Col. 4 |
| 1¼ | 29,430 | $7.568 \times 10^{-3}$ | $11.375 \times 10^{-3}$ |
| 1½ | 13,610 | $3.337 \times 10^{-3}$ | $4.860 \times 10^{-3}$ |
| 2 | 3,904 | $885.5 \times 10^{-6}$ | $1.244 \times 10^{-3}$ |
| 2½ | 1,605 | $344.7 \times 10^{-6}$ | $476.4 \times 10^{-6}$ |
| 3 | 542 | $108.7 \times 10^{-6}$ | $146.7 \times 10^{-6}$ |
| 3½ | 262 | $50.27 \times 10^{-6}$ | $66.69 \times 10^{-6}$ |
| 4 | 139.2 | $25.70 \times 10^{-6}$ | $33.67 \times 10^{-6}$ |
| 5 | 44.98 | $7.737 \times 10^{-6}$ | $9.955 \times 10^{-6}$ |
| 6 | 17.95 | $2.914 \times 10^{-6}$ | $3.832 \times 10^{-6}$ |
| 8 | 4.549 | $678.8 \times 10^{-9}$ | $865.0 \times 10^{-9}$ |
| 10 | 1.459 | $202.9 \times 10^{-9}$ | $234.5 \times 10^{-9}$ |
| 12 | $592.1 \times 10^{-3}$ | $77.85 \times 10^{-9}$ | $87.04 \times 10^{-9}$ |
| 14 O.D. | $360.7 \times 10^{-3}$ | $46.00 \times 10^{-9}$ | $50.89 \times 10^{-9}$ |
| 16 O.D. | $178.6 \times 10^{-3}$ | $21.80 \times 10^{-9}$ | $23.80 \times 10^{-9}$ |
| 18 O.D. | $98.4 \times 10^{-3}$ | $11.59 \times 10^{-9}$ | $12.25 \times 10^{-9}$ |
| 20 O.D. | $56.7 \times 10^{-3}$ | $6.45 \times 10^{-9}$ | $6.785 \times 10^{-9}$ |

or more times greater than the values indicated by the chart and formula. Therefore, good judgment is required in the use of any formula for water flow. For a discussion of the effect of age of pipe, and similar factors, upon the resistance coefficients, reference may be made to Hazen & Williams "Hydraulic Tables" (John Wiley and Sons, New York).

### *The Flow of Compressed Air*

PROBLEM:

One thousand cubic feet of free air per minute are to be transmitted at 100 lb per sq in gage pressure through a 4-in. standard weight pipe. What will be the pressure drop due to friction?

SOLUTION by CHART:

Enter the chart at the top, at the point representing 100 lb per sq. in. gage pressure, and proceed vertically

downward to the intersection with a horizontal line representing 1000 cfm, then parallel to the diagonal guide lines to the right (or left) to the intersection with a horizontal line representing a 4-in. pipe, then vertically downward to the pressure loss scale at the bottom of the chart, where it is observed that the pressure loss would be 0.225 lb per sq in. per 100 ft of pipe.

Four quantities are involved in the use of this chart, namely, air pressure, rate of flow, pipe size and pressure loss. The chart may be used to determine any one of the foregoing data, provided the remaining three are known.

SOLUTION BY FORMULA:

The chart is based upon the Harris formula (University of Missouri Bulletin, Vol. 1, No. 4—1912) which is: $p = \frac{cL}{r} \times \frac{Q^2}{d^5}$, where $p$ is pressure drop due to friction in pounds per square inch, $c$ is an experimental coefficient and equals $\frac{0.1025}{d^{0.31}}$, $L$ is the length of pipe in feet, $r$ is the ratio of compression (referred to atmosphere) at the entrance to the pipe, $Q$ is the rate of air flow through the

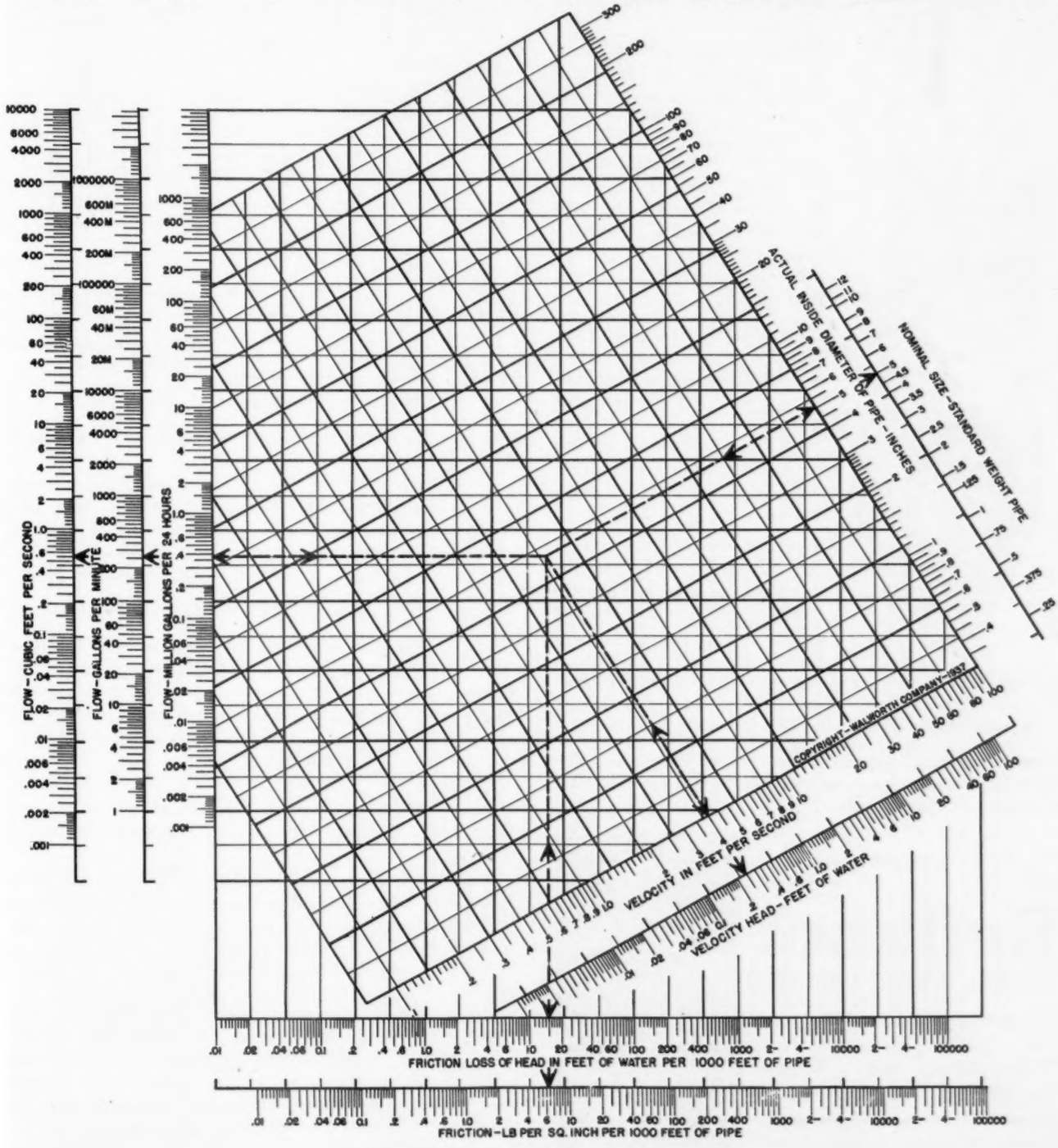
FLOW - CUBIC FEET PER SECOND
FLOW - GALLONS PER MINUTE
FLOW - MILLION GALLONS PER 24 HOURS
ACTUAL INSIDE DIAMETER OF PIPE - INCHES
NOMINAL SIZE - STANDARD WEIGHT PIPE
COPYRIGHT - WALWORTH COMPANY - 1937
VELOCITY IN FEET PER SECOND
VELOCITY HEAD - FEET OF WATER
FRICTION LOSS OF HEAD IN FEET OF WATER PER 1000 FEET OF PIPE
FRICTION - LB PER SQ. INCH PER 1000 FEET OF PIPE

**Chart for calculating flow of water in pipes**

Use of the chart involves rate of flow, pipe size, friction and velocity, any two of which establish a point of intersection from which the other two can be found. The charts and formula are a part of similar data prepared by the author for inclusion in the Engineering Data Section of the forthcoming General Catalog of Walworth Company

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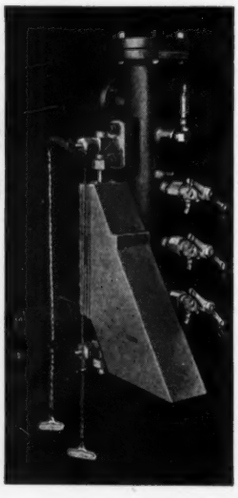

53 years of reliability are behind this Reliance No. W650 Forged Steel Alarm for 600 lb. boilers at Fort Bend Utilities, Sugarland, Texas. Guaranteed unsinkable Reliance Stainless Floats and 2000 lbs. pressure equipment.


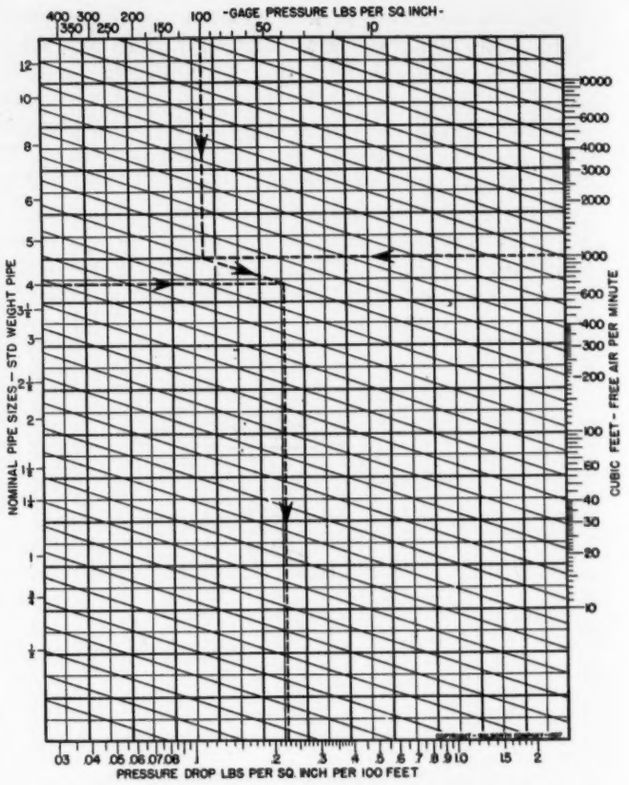
400 300 200 100 -GAGE PRESSURE LBS PER SQ INCH-
350 250 150 50 10
NOMINAL PIPE SIZES – STD WEIGHT PIPE
CUBIC FEET – FREE AIR PER MINUTE
PRESSURE DROP LBS PER SQ INCH PER 100 FEET

**Chart for calculating flow of air in pipes**

pipe in cubic feet of free air per second and $d$ is the actual internal diameter of the pipe in inches.

Substituting the value of $c$ in the foregoing formula and changing the nomenclature so that $Q$ is cubic feet of free air per *minute* and $p$ is the pressure drop in pounds per square inch *per 100 ft of pipe*, the author suggests the following modification of the original formula:

$p = \frac{Q^2 \times F}{P}$, where $p$ is the pressure drop due to friction per 100 ft of pipe, $Q$ is the rate of flow in cubic feet of free air per minute, $P$ is the initial pressure at the entrance to the pipe in pounds per square inch *absolute* and $F$ is a factor which is a function of inside diameter of the pipe ($d$ in inches), combined with the formula constant. Its value is: $\frac{0.04185}{d^{5.31}}$. For convenience in the use of the formula, values of $F$ for nominal pipe sizes are tabulated in Columns 3 and 4 of the accompanying table.

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The October issue of COMBUSTION contained a steam flow chart similiar to the water and air charts in the present article. The author desires to point out that an error inadvertently appeared in the lower section of the scale of *actual inside diameter*, and that this scale as printed should not be used for pipe below 2 in. diameter. For exact computations in this range, the simplified formula should be used. However, the correct scale can be approximated by laying off from the present scale the values 20, 16, 14, 12, 10, 8 and 6, then sliding this dummy scale along until the "20" coincides with the present "2." Then 16, 14, 12, etc., will represent 1.6, 1.4, 1.2, etc., respectively, giving pressure loss values slightly low.

The scales for standard and extra strong pipe require no correction.

# STEAM POWER DEVELOPMENTS

By C. W. E. CLARKE, Consulting Engineer
United Engineers & Constructors, Inc.

**This is an abstract of a paper which the author presented at the 33rd Convention of the Association of Iron and Steel Engineers at Chicago, September 28 to October 1, 1937. The original paper, together with forty-three illustrations, gave an exhaustive review of present steam station practice, particularly among the utilities and large industrials, such as would be applicable to steel plant service. This will be published in full by the Association at a later date.**

POWER demands of the steel industry are fast assuming proportions comparable to those of utility plants. The introduction of modern rolling methods is a contributory factor in this rapid increase and it will not be long before the larger steel companies will have use for units with capacities of about 50,000 kw.

With this in mind it is natural that one should look, as a guide, to the intensive development of the utility power plant in which steam pressures, steam temperatures and sizes of boiler and generating units have increased rapidly.

In general, the larger the boiler and generating units, the lower becomes the cost per kilowatt of installed capacity. This has been one of the principal incentives for utilities to install larger units. Turbine-generators rotating at 3600 rpm are being built up to 50,000 kw and consideration is being given to 75,000-kw units at this speed. It is interesting to note the comparative size and weight of turbine rotors of the same capacity at speeds of 3600 and 1800 rpm. The 3600-rpm rotor of a 25,000-kw unit weighs 23,000 lb while the 1800-rpm rotor weighs 108,000 lb.

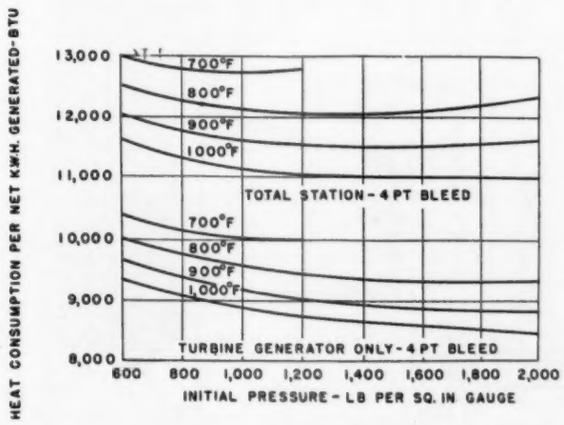


**Fig. 1—Attainable heat rates with higher pressures and temperatures**

Due to advances in pressures and temperatures overall plant efficiency has been substantially increased. Today it is possible to obtain an overall plant thermal efficiency of about 30 per cent whereas ten years ago 23 per cent would have been considered excellent.

The advances in pressure, temperature and size of units have been made possible by:

1. Development of the chrome-nickel and molybdenum alloys, which in turn have allowed a construction in machines, pipe and other pressure parts which copes with the increased stresses developed by the higher pressures and temperatures.

2. Improvements in welding and manufacturing processes. The welding art has been largely responsible for many of the advances, permitting as it does the construction of heavy pressure parts and eliminating, for instance, bolted joints in piping systems which are particularly subject to difficulty through creep.

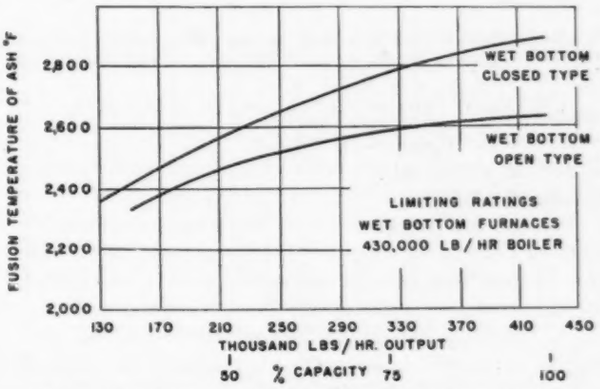


**Fig. 2—Limitations of load with wet-bottom furnaces**

3. Better knowledge of physical properties of steam, especially at the higher pressures and temperatures.

Fig. 1 indicates attainable heat rates with higher pressures and temperatures. Note that the curves for the prime mover show a constant decrease with increasing pressures and temperatures, while the overall plant curve flattens out with the higher pressures. This is due to the power required for operating auxiliaries, particularly feed pumping equipment.

Increased boiler sizes have imposed more difficult problems on firing equipment. In general, for larger units, pulverized coal is used. It is particularly flexible as it puts no limitations on boiler size or on the quantity of fuel which can be fired. Further, the poorer grades of coal can be burned better with this system of firing than with stokers. Boilers can be kept on the line longer, as the combustion equipment subject to outage is outside the furnace and higher air temperatures can be used. Units of large capacity are in many cases tan-

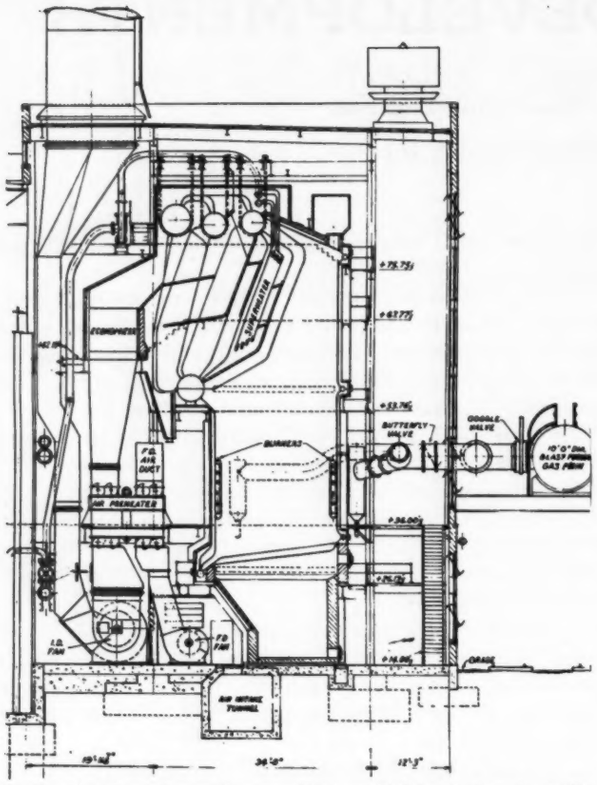

**Fig. 3—Section through one of three boilers being installed at South Chicago Works of the Carnegie-Illinois Steel Corp.**

gentially fired. Finally, and this is of considerable value to the steel industry, pulverized fuel can readily be burned in combination with other fuels such as blast furnace gas, coke oven gas, natural gas and oil.

Furnaces for pulverized coal firing employ one of two types of bottom or ashpit—the dry or the wet bottom. The former has certain advantages in that, without limitations as to capacity in the lower ranges, fuels of widely varying ash-fusion temperature can be safely burned. The wet-bottom type is particularly adaptable to fuels of relatively low ash-fusion temperature, although it has been used for coals with ash-fusion temperatures as high as 2600 to 2700 F. The wet-bottom furnace has one advantage in that it traps a certain amount of the fly ash which in a dry-bottom furnace would either deposit throughout the boiler or pass out with the flue gases.

Fig. 2 indicates some of the limitations as to capacities at which a wet-bottom furnace can be operated, particularly below half load. Note that there are two curves, one for a closed and the other for an open-bottom furnace. In the latter type the boiler surface is subject to the radiant effect of molten ash in the bottom. The closed type is so termed because the boiler heating surface is not subject to the radiant effect of the fluid ash. Closed-bottom furnaces are usually designed on the basis of a much higher heat liberation than other types, that of the West End Station in Cincinnati being designed for a heat liberation of 80,000 Btu per cu ft per hr. Originally wet-bottom furnaces were tapped intermittently but continuous tapping is now coming into favor.

Although pulverized coal has replaced stoker firing to an appreciable extent, stoker manufacturers have not been idle. Where formerly a combustion rate of 40 to 50 lb per sq ft of grate was considered the maximum, now 85 lb is attainable. The increase has been accomplished by better air distribution and better stoker control. For use with coals of low ash fusion temperature a water-cooled stoker has been developed. The water cooling is not in the boiler circulation and, of course, in some cases this works to a disadvantage in a proper heat cycle.

Fig. 3 shows a boiler designed to burn blast furnace gas in combination with natural gas and oil and is so arranged that pulverized fuel firing can be supplied without any changes in the setting. The burners are located at the corner, providing for tangential firing. Three of these boilers are now being installed in the South Works of the Carnegie-Illinois Steel Corporation. They are of 300,000 lb per hr capacity and will operate at 450 lb pressure and 750 F.

Fig. 4 shows an extremely high-pressure boiler to be installed in the Twin Branch Station of the American Gas and Electric Company. This boiler will operate at 2500 lb pressure, 940 F, and have a capacity of 550,000 lb per hr.

The principal advances in turbine-generator design have been in size of units, increased speeds and greater thermal efficiencies. A large part of the latter item is due to the higher pressures and temperatures used. The quantities of steam involved in operating large condens-

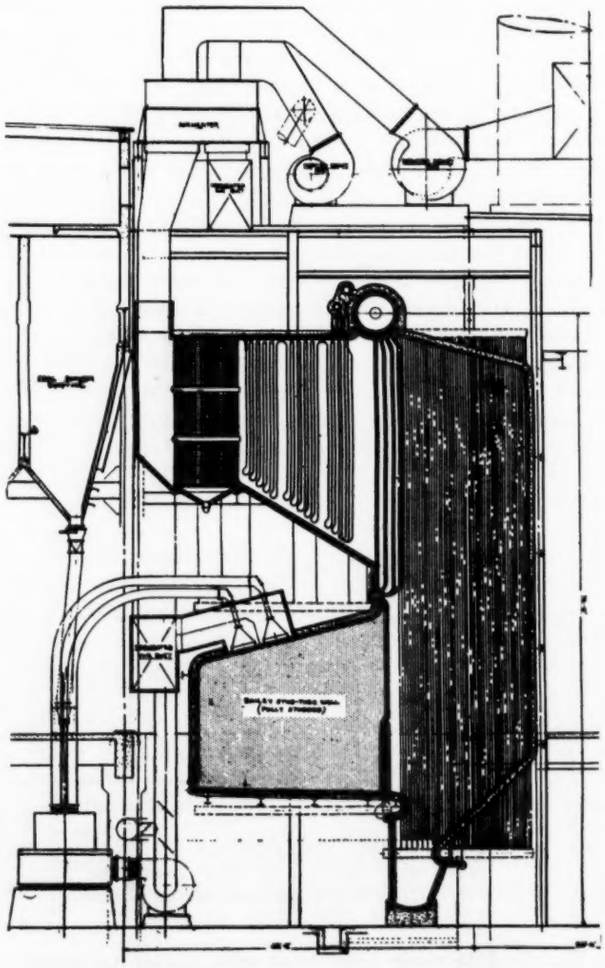

**Fig. 4—High-pressure boiler for Twin Branch Station**

ing turbines requires blades of unusual size. Tip speeds are in the neighborhood of 75,000 fpm and most large low-pressure elements are made double flow to cut down the blade size. Turning gears are now in general use on the larger units so that, in starting up, uniform temperature can quickly be reached in the rotor.

An interesting development is double-wall construction for high-pressure turbine cylinders. The space

Hydrogen's thermal conductivity is seven times that of air while its specific heat is practically the same. Also the heat transfer coefficient from surface to gas is one-third greater than with air.

2. There is increased life of insulation because of absence of oxygen and moisture in the presence of corona.

3. Complete elimination of effects of corona in the windings increases the possibility of raising generator

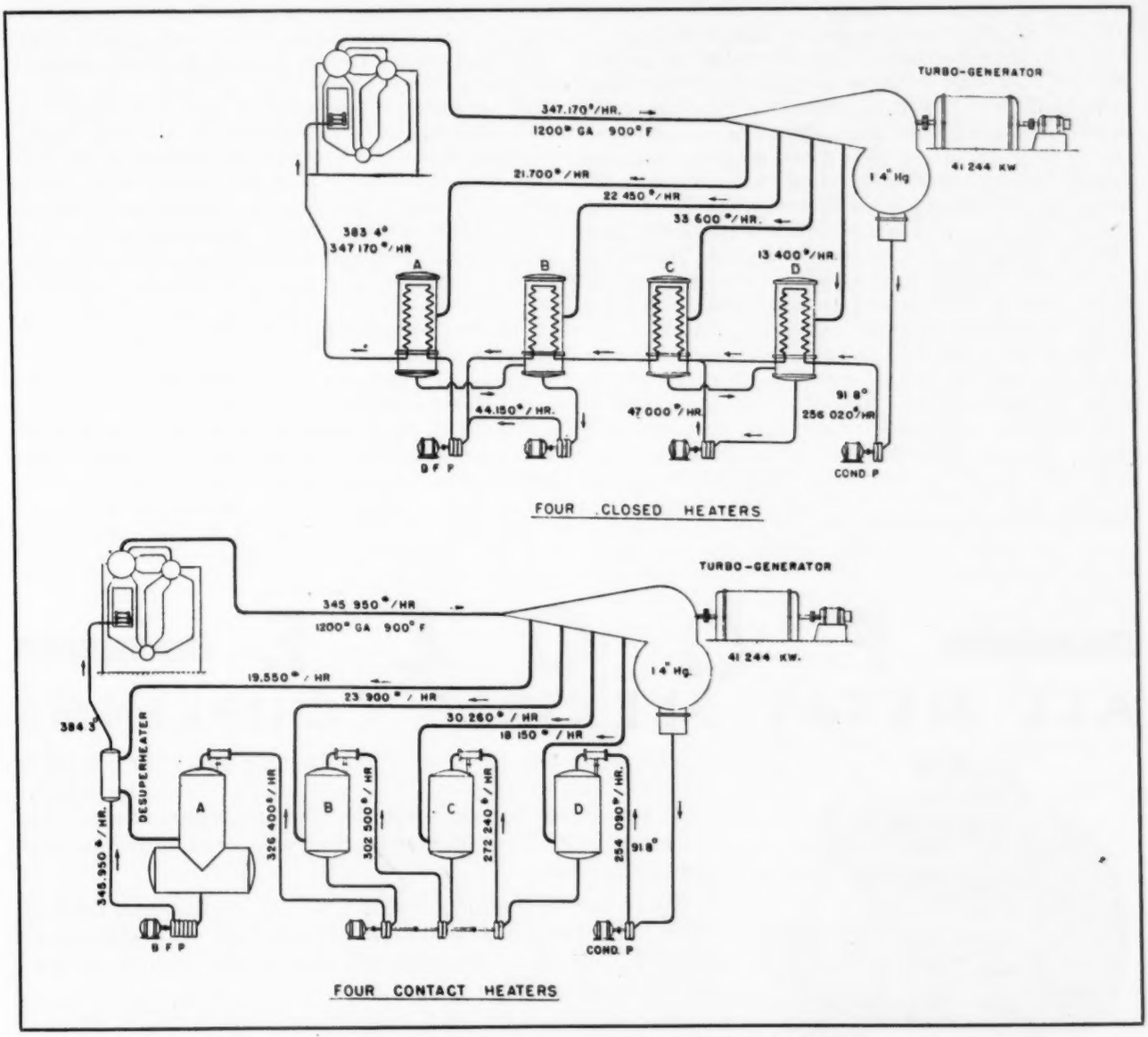


**Fig. 5—Comparison between contact and closed heaters**

between the turbine casing walls is subjected to bleeder pressure, so that the pressure differentials between the turbine casings are reduced, which permits the use of relatively thin cylinder walls, thus reducing stresses and other difficulties in these walls due to uneven heat in starting or in changes of the load.

A considerable percentage of the larger generators now being constructed are arranged for hydrogen cooling. This has several important advantages as follows:

1. Windage losses and noise are reduced as hydrogen is about one-quarter as heavy as air. The increase in efficiency due to this item approximates $1^1/_2$ per cent.

voltages. Heretofore, 22,000-volt generators have been considered doubtful. Hydrogen cooling should make them satisfactory.

Feedwater heating by extracted steam and improvements in tube spacing and steam laning have reduced condenser cooling surface requirements per kilowatt of output.

Muntz and Admiralty tubes have been almost universal for condensers located on fresh water. For sea water, or brackish and contaminated water, the problem becomes more involved. Copper, arsenical copper, aluminum brass and other alloys are used. Modern

operating conditions require condenser leakage to be kept at a minimum. This has resulted in the expanding of condenser tubes into the tube plates at both ends.

Many plants have experienced difficulty with slime deposits and algae on the inside of tubes. Intermittently chlorinating the cooling water before it enters the tube has proved beneficial in nearly every case. It is not a very complicated process and is subject to accurate control which makes it entirely safe.

Unless steam-driven auxiliaries are highly desirable for some specific reason, feedwater in modern plants is heated by steam extracted from the turbine at various stages. Four-stage bleeding is general and five-stage is becoming so. The more stages bled, the higher the overall plant efficiencies, although the cost of increasing the number of stages should be carefully balanced against the savings. Since extraction heating has become general, closed feedwater heaters have been used almost exclusively. There has been a recent development involving the use of open or contact heaters for this work. Contact heaters produce a slightly higher temperature in the feedwater, as it is possible to heat the steam to saturated temperature, but in general this system costs more than the closed system, due principally to the cost of the extra pumping equipment. Fig. 5 shows a comparison between contact and closed heaters.

When all the condensate is returned to the system, the small percentage of makeup is generally supplied by an evaporator placed in the heat cycle. With present treating methods it is possible to operate high-pressure boiler plants satisfactorily with 100 per cent makeup. Some types of water may restrict the capacity of a boiler but there are a sufficient number of installations operating under these conditions so that there is no doubt about the success of operation with 100 per cent makeup.

Selection of fan drives and control of fan output becomes more and more important with increased requirements for auxiliary power. For smaller fans, damper and vane control is generally satisfactory and economical. With the larger fans, the power costs warrant the use of variable-speed drives. One such drive that is widely used is the hydraulic coupling which allows control over a range of 20 to 98 per cent of the motor speed. Under boiler load changes the speeds of the forced- and induced-draft fans change almost proportionately. In some recent installations the induced- and forced-draft fans are combined in one unit driven by one prime mover.

Developments in boiler feed pumps have been principally along the lines of perfecting designs for the higher pressures. Boiler pressures of 1000 lb and over and temperatures of 400 to 500 F necessitate great care in balancing the rotor hydraulically and also in preventing leaks and distortion. Most of the high-pressure feed pumps are operated at about 3600 rpm. In some cases forged steel casings, vertically split, are used to avoid leaky joints and castings.

While one would not expect that the steel industry would find it advisable at the present time to make installations at the extreme pressures and temperatures outlined above, as the use of these pressures and temperatures becomes more and more general and their reliability is proved, the natural tendency of the industry is going to be toward installations in the future of larger units with increased pressures and temperatures.


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**The sectionalized view of the POOLE FLEXIBLE COUPLING reveals its simplicity of construction. Note the positive gear contact with crowned teeth giving support at their outside diameter where lubrication is always maintained through centrifugal force.**

**There are no flexing materials to require frequent replacement. Its Gear Tooth double engagement with spherically formed outer faces permits self alignment without binding action at any point.**

**The POOLE FLEXIBLE COUPLING is suitable to all conditions of service. It operates equally well in either direction, continuous or reversing, and at high or low speeds. Its strength is greater in all cases than the connecting shafts. It is self contained, symmetrical in design and completely protected from dust and dirt.**

**Its large area of lubricated surface permits an effectual cushioning of torsional shock. The POOLE FLEXIBLE COUPLING is a high grade product built by makers of fine machinery for more than ninety-four years.**

## Poole Foundry & Machine Company

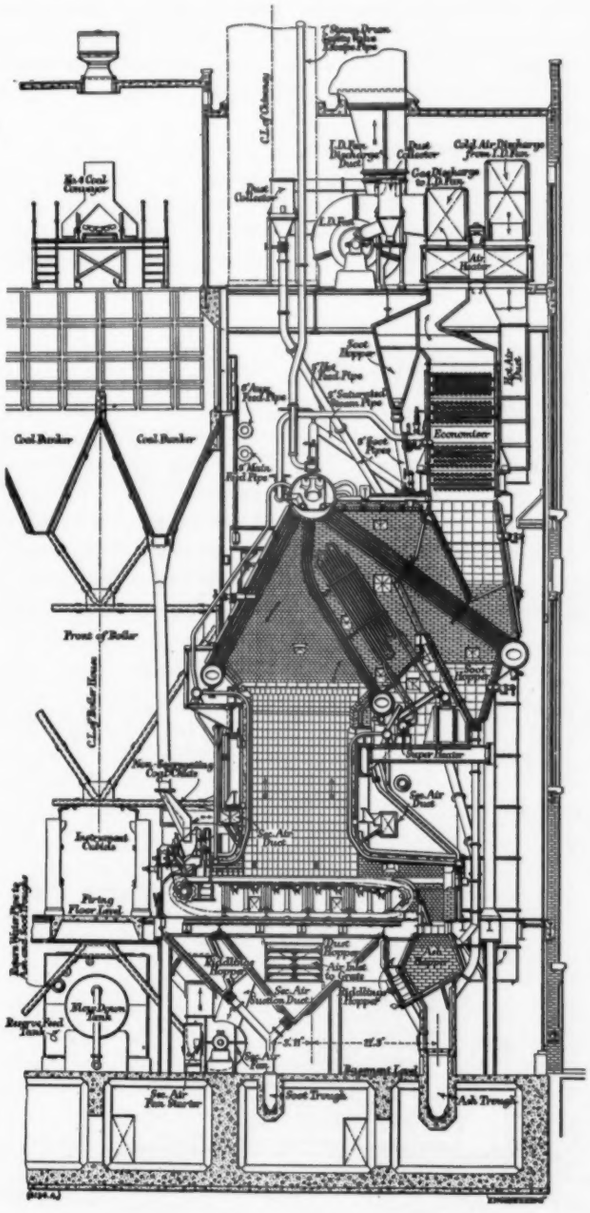
**Baltimore, Maryland**

# STEAM ENGINEERING ABROAD

## As reported in the foreign technical press

### Dalmarnock Extension

Dalmarnock Power Station, which serves the City of Glasgow, Scotland, is being extended by the addition of six 160,000-lb per hr boilers and two 50,000-kw turbine-generators. Three of the boilers and one turbine were placed in operation on October 1 and the remaining units will be completed within a year. This extension is described in detail in the October 8 issue of *Engineering* (London).




Cross-section through Dalmarnock boiler

Construction on the original station was begun in 1914 but, owing to the War, it was not completed until 1920. The installation consisted of sixteen 150,000-lb per hr stoker-fired boilers supplying steam at 270 lb, 700 F, to five 18,750-kw turbine-generators. In 1926 eight 50,000-lb per hr boilers and two turbine units of 25,000 kw and 18,750 kw were added. Work on the present extension was begun in 1935.

The new boiler units (see the accompanying cross-section) are of the Yarrow four-drum type designed for a pressure of 625 lb per sq in. and 850 F total steam temperature. Forged drums with riveted heads are employed and the tubes are 2 in. and $2^1/_4$ in. outside diameter.

Each boiler is fired by a B & W twin stoker of the semi-drop link type, each 28 ft wide by 18 ft long, giving a grate area of 504 sq ft. Block-covered water walls are employed having a surface of 1144 sq ft as compared with 15,630 sq ft of boiler heating surface and the furnace volume is 8615 cu ft giving a heat release at maximum rating of about 25,000 Btu per cu ft.

In order to provide a constant steam temperature the MeLeSco superheaters are divided into two sections, arranged in series and regulation is effected by cooling the steam in a non-contact type desuperheater located between the sections.

Gilled-tube economizers and regenerative-type air heaters, two per unit, are provided.

Four-point extraction from the main turbines is employed to heat the feedwater to 320 F.

### Drop Condensation of Steam

In surface condensation investigations the heat transfer is generally studied in three steps, namely, that from steam to wall, that through the wall and that from the wall to the cooling medium. The first may vary considerably since the condensate may form in drops or in a continuous water film, depending upon the condition of the surface; and the heat transfer for drop condensation is six to eight times that for film condensation.

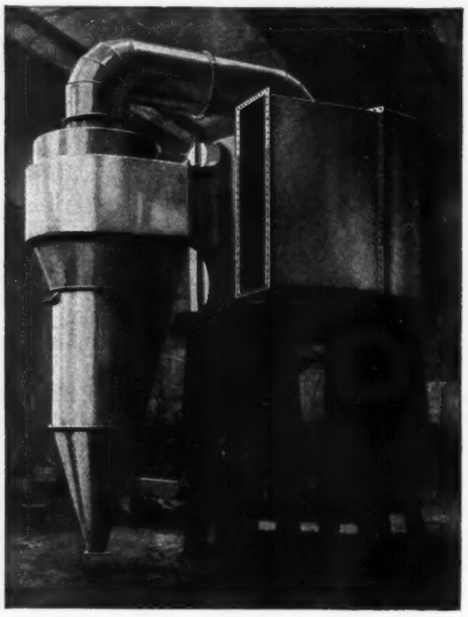
Although film condensation has been studied exhaustively, drop condensation has not received as much attention, hence the investigations of E. Gnam, as reported in the July 1937 issue of *Zeitschrift des Vereines deutscher Ingenieure* are of interest.

The author conducted experiments on drop condensation for saturated and superheated steam on a vertical brass tube, after having ascertained that drop condensation could be produced on a polished surface as well as on the moderately rough surface of a cooler if the latter had been treated with substances onto which the adhering force of the condensate was less than its surface tension.

## What do you know about

# BUELL FLY-ASH COLLECTORS

**(van Tongeren System)**



ASK yourself this question frankly. Like most others you will probably confess having given any fly-ash collector little thought. You realize that something of the kind must be used and probably you believe that one make is about like another.

Early design of cyclonic dust collectors was largely guess work, and was improved little in 25 years. No effort was made to counteract the effect of the double-eddy current in causing dust puffs and in greatly reducing dust-collecting efficiency, nor did anyone worry about serious differences in the efficiency and in the amount of resistance to gas travel at different loads.

## BUELL HIGH-EFFICIENCY DUST COLLECTORS

definitely correct these glaring faults. Their provision for converting double-eddy current from a largely detrimental to a fully helpful factor, and their employment of adjustable vanes in the cleaned-gas discharge for keeping the fly-ash-extracting efficiency high and the resistance low *under widely varying loads* are fundamental advances. Only with these features can the requirements of critical public authorities be met, and the fly-ash nuisance eliminated efficiently.

Buell Fly-Ash Collectors have substantially increased the practical percentage of dust elimination in many plants.

If fly ash from your plant is a neighborhood nuisance or a menace to your processes and products, or if you wish to recover dust for its commercial value, let us advise you free, suggest suitable installation and submit performance guarantees.

## BUELL ENGINEERING COMPANY, INC.

**Engineers of Dust Collector Equipment**

70 Pine Street New York


Most oils and fatty substances satisfied this condition provided the surface had not previously been covered with alkaline fluids; in that case, the condensate spread over the surface in the form of a film. Temperature measurements were made by thermo-couples.

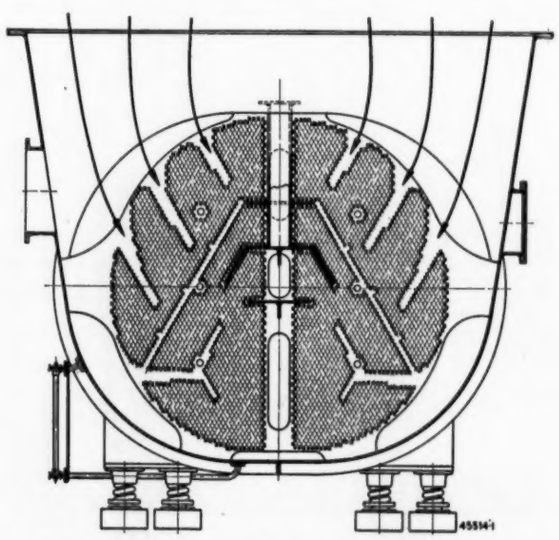
It was found that the time required for a drop to form diminished with increase in load, and at constant load was independent of the steam pressure and velocity. The mean transfer rates from steam to wall showed dependency upon the prevailing condenser pressure and steam velocity very similar to the case of film condensation. Steam velocity, however, has a greater influence upon the heat transfer for drop condensation than it has in film condensation. The explanation advanced is that with drop condensation form resistance becomes a factor whereas with film condensation there is only a shearing action involved.

The heat transfer rates for flowing steam were 50,000 Kcal/m²/h/deg C at 2.27 lb abs and approximately 125,000 Kcal/m²/h/ deg C at 12.8 lb abs condenser pressure. With stationary steam and atmospheric pressure a mean transfer rate of 68,500 Kcal/m²/h/deg C was measured. The high transfer rates from steam to wall may prevail only if the transfer rates from wall to water are of an equally high order.

Finally, further investigations were conducted for both drop and film condensation to determine whether saturated or superheated steam yielded the better transfer rate. For both forms of condensation, steam superheated about 100 deg C gave 7 per cent better results.

## Condenser at Oslo

*The Brown Boveri Review* for August 1937 contains a very complete description of the Rosenkrantzgate steam power station at Oslo, Norway. This station has now been in operation for some time and its Velox steam generators have been previously described. An interesting feature brought out in the article is the tube arrangement of the condenser. The 32,000-kw turbine is of the single-cylinder type with double-flow (inward) low-pres-



**Tube arrangement of Brown Boveri condenser**

sure stages exhausting at a very high vacuum due to the low temperature of the condensing water which averages 41 F.

A cross-sectional view of the condenser is here reproduced. This shows that instead of the steam being directed through a wide V-shaped central passage between the tube stack halves, as is usual in Brown Boveri practice, the stack of cooling tubes is subjected to the flow of steam from the outside and over its whole periphery. This arrangement is as advantageous from the point of view of the utilization of material, as the well-known "OV" principle, the resistance to flow of the steam is as low and is further reduced by the deep channels. Deaeration is accomplished in the central tube-stack zone, and a considerable number of tubes are there reserved for air cooling.

## High-Pressure Heat Storage for Standby Station

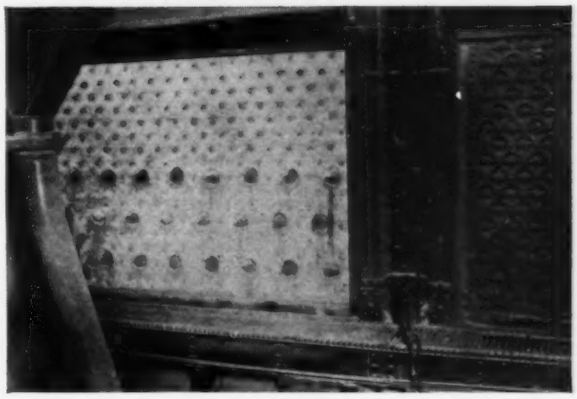
According to *Zeitschrift des Vereines deutscher Ingenieure* of September 4, a 500-lb, 200,000-lb per hr La Mont boiler and high-pressure steam storage is being installed in the Simmering Municipal Power Plant of Vienna. This is a standby station, supplementing hydro power from a transmission system, and in case of line interruption a relay automatically supplies the standby turbines from the steam storage system until the boiler can be brought up to full capacity. The boiler is provided with both oil and pulverized coal firing and the eight 50-in. storage drums are capable of delivering steam at the rate of 240,000 lb per hr for the first four minutes. These drums are designed for 1700 lb per sq in. pressure and are charged by steam from an oil-fired forced-circulation boiler. They are maintained at pressure and temperature by a heat exchanger through which passes the steam to the house turbines.

## Moisture Deposits in Regenerative Heaters

H. Hausen, discussing this subject in the August 7, 1937, issue of *Zeitschrift* V. D. I, says that, "In addition to yielding excellent heat exchange the regenerative type heater offers the advantage that the air need not be freed from water vapor and $H_2CO_3$ before entering. These constituents of the air deposit during the warming period by condensation on the mass of metal and are evaporated and carried away by the cold gas during the other half of the cycle."

While these occurrences may be fully analyzed if one knows the temperature of the gas, that of the metal and the condensible constituents of the air, the author, by making certain assumptions, proceeds to develop a single differential equation containing only one unknown, namely, the temperature of the metal. From this he constructs a graphical solution, which shows that, when using dry air, the temperature of almost the entire regenerator rises according to a straight line, but when using moisture laden air the temperature drops along a curve during the heating period. In the colder portions where the moisture deposit is not noticeable, the temperature curve is still linear but much steeper than for dry air. The temperature during the cooling period follows a similar trend and in the zone of water vapor removal it falls off very fast at first, then slowly.


# EAGLE
## Super "66"
## *Stops Heat Waste*
## on Boiler Headers



**Boiler header** at left covered with Eagle Super "66." Boiler at right was later insulated with same material. High coverage, with minimum shrinkage, makes this easy-to-apply plastic insulation extremely economical. (Union Electric Light & Power Company, St. Louis.)

### Improved Plastic Insulation pays for itself in a few months . . . quick, easy to apply

● It's easy now to stop costly heat loss through boiler headers. These surfaces, with their enormous radiating area, can be quickly covered with Eagle Super "66."

This improved plastic insulation trowels easily on any surface—turbines, boiler drums, flanges and fittings, as well as steam headers.

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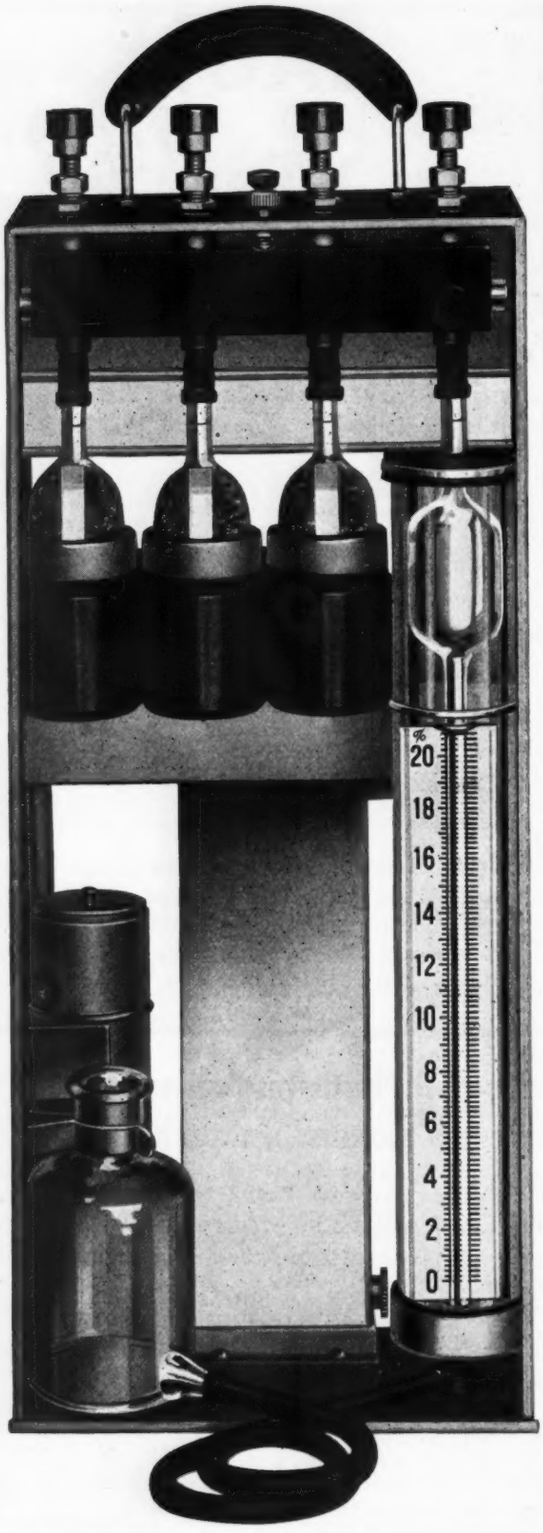
**INDUSTRIAL INSULATION**

ELLISON GAS ANALYZER

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Monel case 4½x8x18″ with draft gage and thermometers. Hard rubber header and glass valve stem, corrosion proof. Needle valves thruout, swivel joint, leak proof, no grease. Curled hard rubber in absorption bells. White capillary background and vision panels, solutions visible several feet away. White scale 7 to 8″ long. Jacket filled with glycerine. Air bell, replacing air bag. Automatic zero leveling. Accurate and speedy.

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## Income in the Engineering Profession

The Bureau of Labor Statistics, U. S. Dept. of Labor, has issued the sixth of its series of reports prepared by Andrew Fraser, Jr., based on data from its survey of the engineering profession which was undertaken in 1935 at the request of the American Engineering Council. This report deals with "Annual Income in the Engineering Profession, 1929 to 1934." A summary of the findings follows:

"In 1929 there was greater spread in the earnings of engineers engaged in non-engineering work than in those obtained from engineering work. Thus, among engineers 40 to 47 years of age, 10 per cent of those engaged in non-engineering earned more than $12,424 and 10 per cent earned less than $2420 per year. The respective annual incomes of similar proportions of all those engaged in engineering work were $9615 and $2705; and of graduates in engineering $10,088 and $2936.

"The age of maximum earning power for engineers arrives more quickly for non-engineering than for engineering work. At 48 to 55 years of age, however, those college graduates who stayed in engineering were doing as well as those who had gone into non-engineering work. This was true even at the highest income levels.

"Despite the fact that in 1929 the tendency was for average annual incomes of engineers engaged in non-engineering to exceed slightly those from engineering work, the opportunities in the former field did not embrace more than 7 per cent of the total in any one age classification.

"Over the period 1929 to 1934 the relationship changed between the jobs engineers took in engineering and non-engineering work. On the whole, it appears that in 1929 non-engineering work was an alternative to engineering work, but from 1929 to 1934 many non-engineering jobs were accepted as an alternative to unemployment or work relief.

"The extent to which earning opportunities from non-engineering work depreciated between 1929 and 1934 differs at the various age levels. The average earnings of two groups in non-engineering who were 28 to 40 years in 1929 declined by almost one-third from 1929 to 1934. As between the groups that were over 48 years in 1929 the average income of the 1934 group is only one-half the average of the 1929 group. Similarly at each of the other income levels a greater fall is found in the average income of older men in non-engineering.

"Those who were able to stay in engineering fared better. Furthermore, the changes which occurred in the earnings from engineering work, as reported by all engineers and by graduates only, were consistently uniform.

"The relative changes as between non-engineering earnings and those for engineering work of engineers, with advancing age and experience, are also found to be the same for men with comparable periods of experience.

"It was among those newcomers who were trying to force their way into the profession that the greatest fall in income occurred. Thus average earnings in engineering in 1934, two years after graduation, were 37 per cent less than in 1929. The earnings of those who had been out of college ten years were 31 per cent lower in 1934 than in 1929. At higher ages all groups averaged a decrease of 26 per cent."

# A.S.M.E. Annual Meeting Program

The tentative program for the Annual Meeting of the American Society of Mechanical Engineers, December 6 to 10, in New York, has just been announced. It includes a large number of papers among the various technical divisions, but the following are of particular interest to steam power engineers.

*Tuesday afternoon, 2 p.m.*

SESSION ON CRITICAL-PRESSURE BOILERS

Progress Report of an Investigation of the Oxidation of Metals by High-Temperature Steam, by A. A. Potter, H. L. Solberg and G. A. Hawkins

Protecting Steel from Intercrystalline Cracking in Aqueous Solutions, by W. C. Schroeder, A. A. Berk and R. A. O'Brien

Decomposition of Sodium Sulphite Solutions at Elevated Temperatures, by F. G. Straub

Some Results from the Research on Flow Nozzles, by Howard S. Bean and Samuel R. Beitler (To be read by title)

SESSION ON HIGH-TEMPERATURE JOINTS

Welded Joints, by F. L. Everett and Arthur McCutchan

High-Temperature Joints, by Joseph Marin

Bolted Joints for High-Pressure Vessels, by E. O. Waters

Practical Aspects of Turbine Joints, by C. B. Campbell

Effect of Temperature Variation on the Creep Strength of Steels, by E. L. Robinson

*Wednesday morning, 9:30 a.m.*

POWER SESSION

Prevention of Slime in Steam Condensers, by R. B. Martin

Further Studies of Three-Dimensional Pipe Bends, by William Hovgaard

HEAT TRANSFER SESSION

Experimental Investigation of the Influence of Tube Arrangement on Convection Heat Transfer and Flow Resistance in Cross Flow of Gases over Tube Banks, by Orville L. Pierson

Experimental Investigation of Effects of Equipment Size on Convection Heat Transfer and Flow Resistance in Cross Flow of Gases over Tube Banks, by E. C. Huge

Correlation and Utilization of New Data on Flow Resistance and Heat Transfer for Cross Flow of Gases over Tube Banks, by E. D. Grimison

Heat Transfer to Boiling Liquids, by W. H. McAdams and George A. Atkin

*Wednesday afternoon, 2 p.m.*

POWER PANEL DISCUSSION

New High-Pressure, High-Temperature Power Stations. Discussion will cover, the solution of unusual construction problems; capacity and efficiency performance data; troubles with equipment; starting-up procedure. To be discussed by, J. F. Muir, D. S. Brown, A. E. Grunert, C. H. Spiehler, E. H. Krieg, Louis Elliott, G. T. Shoemaker, J. A. Reich, J. N. Landis and W. E. Caldwell

*Thursday morning, 9:30 a.m.*

FUELS SESSION

Water-Cooled Underfeed Stokers, by Joseph S. Bennett

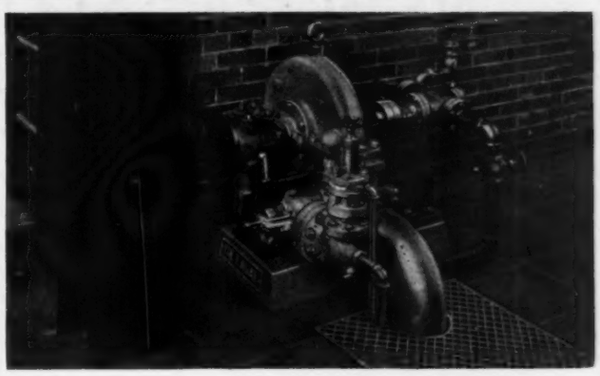
Industrial Power Plants, by C. D. Boomhower

*Thursday afternoon, 2 p.m.*

FUELS SESSION

Panel Discussion on Chemically Treated and Dedusted Coal; Deslagging of Boiler Surfaces

Of the non-technical events, the Annual Business Meeting will take place at 4:00 p.m. on Monday. Tuesday evening will be devoted to the conferring of honors, and the Annual Dinner will be held as usual at the Hotel Astor on Wednesday evening. A number of interesting excursions have been planned, including visits to the power plant of the S.S. Normandie and to the Waterside Station of the Consolidated Edison Company of New York, Inc., which is undergoing extensive modernization in the form of high-pressure extensions.

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can be *driven by variable speed electric motors or steam turbines under control of a constant pressure governor.* This results in a notably compact, sturdy and efficient unit for "lube" or fuel oil in any volume and against pressures up to 500 lb. or over.

The De Laval-IMO pump is of the rotary displacement type, having not more than three moving parts, no valves, no bearings, no timing gears and only one stuffing box, which is under suction pressure. All parts are accessible without disturbing piping. There is no pulsation or vibration and the power consumption is small. Full particulars will be supplied upon learning your requirements. Ask for Catalog L-23.

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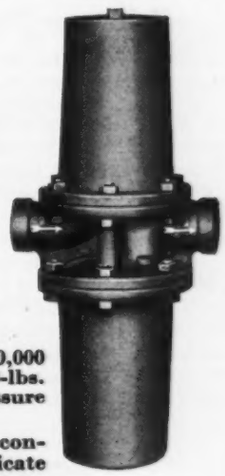

- **Standard sizes for loads up to 240,000 lbs. per hr. continuous flow at 600-lbs. maximum pressure. Higher pressure or larger capacity built on order.**
- **Simple, compact, fool-proof construction. No springs, floats, or delicate mechanism. Only three moving parts.**
- **All the advantages of genuine Armstrong Inverted Bucket Design: Quick opening and closing . . . no wire-drawing . . . non-air-binding . . . self-scrubbing.**
- **Ideal for draining large steam purifiers, separators, flash tanks, continuous blow-down systems, de-superheaters, evaporators, etc.**

***Write for specification sheets.***

**ARMSTRONG MACHINE WORKS**
*814 Maple Street Three Rivers, Mich.*

# NEW CATALOGS AND BULLETINS

**Any of these publications will be sent on request.**

### Condensers

A new 24-page bulletin has been issued by the Foster Wheeler Corporation describing and illustrating its expanded tube condensers. The bulletin is well illustrated with many full page and other smaller photographs showing in detail both the construction and installation of these units. The text discusses the adaptability of this class of equipment especially to stations using very high pressures where contamination of condensate must be rigidly guarded against. Statements from owners concerning the successful operation of several different installations are incorporated.

### Fan Standards

For the convenience of architects, engineers and buyers of fan equipment the National Association of Fan Manufacturers, has available for distribution a bulletin covering "Standard Methods Adopted for Centrifugal Fans and Blowers." Fomerly these standards were published in separate leaflets. It is hoped therefore that fan users will find the consolidated bulletin of value by having available in one place all standards adopted by the Association.

### Feedwater Treatment

The properties imparted to boiler feedwater by a supplemental treatment with a substance merchandised under the name of "Akon" are described in a 16-page pamphlet entitled "The Akon Boiler Feedwater Treatment" just published by the Allis-Chalmers Manufacturing Company. Incorporated in the text is a discussion of the impurities found in water supplies and their detrimental effect on both steam generating and steam consuming equipment. Their partial elimination or transformation by the lime soda and the zeolite processes is then considered and the benefits secured through their further treatment with "Akon" are enumerated.

### Firebrick

The Quigley Company, New York, has issued a new circular which shows in a very unique manner the physical properties of the three different grades of firebrick manufactured and merchandised by that company under the trademarked name of "Insulbrix."

### Industrial Insulation

"Johns-Manville Insulation" is the title of a new 32-page catalog just issued by Johns-Manville, New York, illustrating and describing the many different varieties of industrial heat insulating materials manufactured by that Company. Chapters of particular interest to readers of COMBUSTION would be those on "Insulation for Power Plant Equipment" and "Insulation for Heated Pipe Lines." Other chapters cover sheet and block insulation for heated surfaces; insulating brick; low-temperature pipe insulation; insulating cements; "Sel-O-Cel" concrete and insulating fillers.

### pH and Chlorine Control

A new edition of the handbook, "Modern pH and Chlorine Control" has just been issued by W. A. Taylor & Company, Inc., Baltimore. The first 24 pages of this 65-page manual are devoted to both simple and technical discussions of the meaning of pH control from the standpoints of calorimetric and electrometric methods. This is followed by a discussion of the application of pH control to various problems and detailed descriptions of modern equipment for the control of pH, chlorine and phosphate, and for water analysis. Of particular interest is the section on "Water." The Long Range Slide Comparator and the Dalite Slide Comparator are described and their use explained. Also, the Phosphate Slide comparator, for the control of phosphate in boiler water and the Enslow Slide Chlorimeter, for controlling the chlorine content of condenser water for the prevention of slime are included.

### Pumping Unit

Bulletin No. 5592, issued by Fairbanks, Morse & Company, Chicago, describes its new "Built Together Pump" which is an integral unit consisting of driving motor and centrifugal pump designed to operate against heads up to 475 ft. The motor is of the splashproof type and the pump has two-stage bronze impellers arranged back to back to compensate for thrust. The motor rotor is carried by a single shaft mounted in ball bearings. The pump will handle all liquids low in viscosity and suspended matter and may be mounted in any position. The unit is made in several sizes and with motors having different characteristics.

### Regulator

Bulletin DR 24 just received from the Hagan Corporation of Pittsburgh, Pa., describes the operation of its receiving regulator which is used to convert the impulses received from a primary control device into a mechanical movement which may be used to control a motor, damper, valve or any other control element.

### Rotary Oil Pump

The Imo rotary pump, designed to operate at ordinary motor or turbine speeds is described in Catalog L-32 and Publication L 32-10 issued by the DeLaval Steam Turbine Company of Trenton, N. J. This pump, the moving parts of which consist only of one central rotor and two idling rotors and which contains no valves, bearings, timing or pilot gears and only one stuffing box, is recommended especially for fuel and lubricating oil service. It is available in all capacities and for pressures up to 500 lb. The applications shown in these publications, which are well illustrated, range from small lubricating pumps built into other machines to pumps supplying oil in large quantities to burners in central stations and large steamships.

### Steam Purifiers

The Cochrane Steam Purifier is described in Bulletin 2725 of the Cochrane Corporation of Philadelphia. The uses of this apparatus which is designed to remove the impurities or moisture from steam are fully described and illustrated. Considerable space is devoted to a discussion of the benefits which may be derived from a complete removal of these impurities from steam which is to be used in turbines.

### Steam Traps

The Sarco Company, New York, has just issued a new 32-page booklet entitled "Steam Hook-Ups" which describes the proper use of their various specialties including steam traps, strainers and controlling units. Engineers will find the pages devoted to calculations for determining the sizes of steam traps and the several pages showing typical piping hook-ups for a great variety of heating applications especially useful.

### Steam Turbines

"Modern Turbines to Reduce Costs" is the title of a 12-page brochure issued by the DeLaval Steam Turbine Company of Trenton, N. J. The theme of this publication is the combined effect of high pressure and superheat and bled steam on the reduction of power costs in industries using large quantities of steam for process or heating. The economies resulting from superposing a "top" plant exhausting into the supply mains of a plant already in operation are discussed and enumerated.

### Water Gages and Columns

In a new 16-page bulletin, No. WG1805, well illustrated by photographs and drawings, the Yarnall-Waring Company of Philadelphia present their line of water columns and gages which are manufactured in several different types for pressures up to 1500 lb. The catalog describes in detail not only the construction of the various simple gages manufactured but incorporates as well a description of the Yarway Floatless Hi Lo Alarm Water Column.

# EQUIPMENT SALES

## Boiler, Stoker, Pulverized Fuel

**as reported by equipment manufacturers of the Department of Commerce, Bureau of the Census**

### Boiler Sales

| | 1937 Water Tube | | 1936 Water Tube | | 1937 Fire Tube | | 1936 Fire Tube | |
|---|---|---|---|---|---|---|---|---|
| | No. | Sq Ft | No. | Sq Ft | No. | Sq Ft | No. | Sq Ft |
| Jan..... | 53 | 261,368 | 57 | 287,855 | 64 | 83,389 | 23 | 24,954 |
| Feb..... | 53 | 206,957‡ | 76 | 408,635 | 71 | 87,083 | 47 | 50,094 |
| Mar..... | 142 | 758,733 | 77 | 325,479 | 149 | 210,233 | 53 | 47,411 |
| Apr..... | 63 | 333,169 | 66 | 339,413 | 73 | 67,937 | 74 | 97,401 |
| May..... | 113 | 589,347 | 63 | 328,872 | 82 | 129,782 | 69 | 92,403 |
| June..... | 76 | 330,524 | 145 | 533,703 | 76 | 99,335 | 104 | 131,764 |
| July..... | 82 | 348,417 | 111 | 510,324 | 80 | 98,258 | 74 | 99,479 |
| Aug..... | 67 | 270,646 | 121 | 534,525 | 106 | 136,401 | 85 | 117,834 |
| Sept. ... | 56 | 238,146 | 82 | 371,790 | 76 | 101,524 | 82 | 92,919 |
| Jan. to Sept. Inclusive.... | 705 | 3,369,742 | 798 | 3,640,596 | 777 | 1,013,942 | 611 | 754,259 |
| 1936—12 mos..... | | | 1,179 | 6,086,787 | | | 817 | 980,130 |

### Mechanical Stoker* Sales

| | 1937 Water Tube | | 1936 Water Tube | | 1937 Fire Tube | | 1936 Fire Tube | |
|---|---|---|---|---|---|---|---|---|
| | No. | Hp | No. | Hp | No. | Hp | No. | Hp |
| Jan..... | 63 | 25,278 | 24 | 10,657 | 141 | 21,786 | 139 | 16,840 |
| Feb..... | 45 | 16,591 | 30 | 11,693 | 120 | 20,650 | 98 | 13,567 |
| Mar..... | 80 | 38,074 | 28 | 10,250 | 179 | 24,709 | 105 | 14,605 |
| Apr..... | 72 | 37,185 | 56 | 30,686 | 154 | 23,064 | 99 | 12,844 |
| May..... | 65 | 26,327 | 36 | 16,742 | 137 | 21,443 | 150 | 21,326 |
| June..... | 49 | 19,787 | 58 | 27,546 | 186 | 26,627 | 186 | 23,171 |
| July..... | 79 | 29,207 | 81 | 31,603 | 251 | 34,253 | 255 | 35,615 |
| Aug..... | 58 | 21,998 | 98 | 34,308 | 394 | 53,096 | 336 | 45,960 |
| Sept. ..... | 40 | 11,359 | 62 | 24,416 | 384 | 46,893 | 437 | 50,690 |
| Jan.to Sept. Inclusive.... | 551 | 225,806 | 473 | 197,901 | 1,946 | 272,521 | 1,805 | 234,618 |

| | Water Tube 1936 | | Fire Tube 1936 | |
|---|---|---|---|---|
| | No. | Hp | No. | Hp |
| 1936—12 mos. | 649 | 276,687 | 2,724 | 386,868 |

* Capacity over 300 lb of coal per hour.

### Pulverizer Sales

| | 1937 Water Tube | | | 1936 Water Tube | | | 1937 Fire Tube | | | 1936 Fire Tube | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. | | Cap. Lb | No. | | Cap. Lb | No. | | Cap. Lb | No. | | Cap. Lb |
| | N.† | E.† | Coal/Hr | N.† | E.† | Coal/Hr | N.† | E.† | Coal/Hr | N.† | E.† | Coal/Hr |
| Jan.... | 35 | 7 | 554,900 | 16 | 4 | 235,500 | — | 2 | 1,700 | — | 1 | 1,000 |
| Feb... | 2 | 6 | 68,300 | 9 | 8 | 165,100 | — | 4 | 3,600 | — | 7 | 7,700 |
| Mar... | 59 | 3 | 677,440 | 10 | 6 | 135,300 | 1 | 1 | 2,000 | — | 1 | 800 |
| Apr... | 24 | 1 | 257,100 | 35 | 3 | 639,050 | — | 2 | 1,100 | — | 1 | 1,200 |
| May.. | 22 | — | 276,800 | 22 | 1 | 188,900 | — | — | — | — | 1 | 1,000 |
| June.. | 15 | — | 99,150 | 24 | 7 | 196,100 | — | — | — | 3 | 3 | 10,400 |
| July... | 5 | 6 | 44,250 | 8 | 13 | 158,150 | — | — | — | — | — | — |
| Aug... | 8 | 15 | 211,400 | 18 | 11 | 304,500 | — | — | — | — | 2 | 800 |
| Sept. . | 14 | 3 | 75,900 | 11 | 1 | 82,200 | 2 | — | 2,500 | — | — | — |
| Jan. to Sept.Inclusive | 184•41 | | 2,297,440• | 153 | 54 | 2,104,800 | 3 | 9 | 10,900 | 3 | 16 | 22,900 |

| | 1936 Water Tube | | | 1936 Fire Tube | | |
|---|---|---|---|---|---|---|
| | No. | | Lb | No. | | Lb |
| | N. | E. | Coal/Hr. | N. | E. | Coal/Hr |
| 1936—12 mos. | 269 | 71 | 3,633,845 | 4 | 24 | 30,600 |

† N—New boilers E—Existing boilers.
• Not including 5 new boilers for storage system.
• Not including 167,000 lb coal/hr for storage system.
‡ Revised as a result of correspondence correcting data for February and March.

## Economic Aspects of District Heating

A modern district heating system has an overall thermal efficiency of 63 per cent, according to D. S. Boyden, national president of the American Society of Heating and Ventilating Engineers, who addressed the New York Chapter of that organization October 18. This compares, he said, with efficiencies of 50 per cent for small isolated heating plants and 60 per cent for medium size plants.

The speaker pointed out that district heating began in 1877 when electric utilities began selling exhaust steam for heating at by-product rates. At that time the lines were of screwed pipe, there were no reliable meters and charges were made on a flat rate basis. With the introduction of condensing engines and turbines, use of exhaust steam for heating was dealt a severe blow.

A permanent problem of the district heating utility, Mr. Boyden pointed out, is to keep investment and other fixed charges low enough so that district steam can compete with the isolated plant in spite of its low annual load factor. The investment in a district heating plant is from $2 to $4 per lb of steam capacity; of this, the cost of the distribution lines is from 70 cents to $1.35. The cost of installing steam mains is high, totaling about $37.32 per lineal foot for a 12-in. underground main. This cost is made up of $9.08 for pipe, valves and fittings; $4.84 for insulation; $5.06 for excavating and filling; $3.29 for concrete work; $6.25 for paving; $3.50 for engineering, and $5.30 for extras.

## Business Notes

**Northern Equipment Company,** Erie, Pa., announces the appointment of Cochrane Steam Specialty Company, 80 Federal Street, Boston, Massachusetts, as New England representative for the sales and service of Copes feedwater regulators, differential valves, pump governors, reducing valves, desuperheaters and allied equipment.

**Eagle-Picher Sales Company** announces the following new distributors for Eagle industrial insulating materials: A. Lynn Thomas Co., Inc., Richmond, Va.; Biggs & Company, Wichita Falls, Texas; Cleveland Fire Brick Co., Cleveland, Ohio; Darragh Company, Little Rock, Ark.; Donald Sales & Mfg. Co., Milwaukee, Wis.; Edgar H. Pratt Fire Brick Co., Chicago, Ill.; L. A. Foster Engineering Co., St. Louis, Mo.; L. R. Land Construction Co., Oklahoma City, Okla.; Lunsford Welding Shop, Inc., Jackson, Miss.; Michiana Fire Brick Co., South Bend, Ind.; Tri-State Mill Supply Co., Fordyce, Ark.; Western Windmill Supply Co., Sweetwater, Tex.; Woare Builders Supply Co., Decatur, Ill.

**The Hancock Valve Division of Manning, Maxwell & Moore, Inc.,** Bridgeport, Conn., announces the addition of Charles Velie and Raymond Heath to its corps of field missionary men. Mr. Velie will make his headquarters in Chicago and Mr. Heath will make his headquarters in Dallas. According to M. S. Palmer, sales manager of the Hancock Division, these additions are a part of the Hancock expansion program that is now in progress.

# ADVERTISERS IN THIS ISSUE


Air Preheater Corporation, The
Under Management of The Superheater Company..... 8
American Blower Corporation..... 9
Armstrong Machine Works..... 49
Bailey Meter Company.....6 and 7
Bayer Company, The..... 52
W. H. & L. D. Betz..... 13
Buell Engineering Company, Inc..... 46
Buromin Company, The..... 5
Combustion Engineering Company, Inc.....
.....Second Cover, 10 and 11
DeLaval Steam Turbine Company.....3 and 49
Eagle-Picher Lead Company, The..... 47
Edward Valve & Mfg. Company, Inc., The..... 4
Ellison Draft Gage Company..... 48
Engineer Company, The..... 14
Ernst Water Column & Gage Company..... 52
General Coal Company..... 12
General Electric Company..... 14
Hagan Corporation..... 5
Hall Laboratories, Inc..... 5
Ingersoll-Rand Company.....Third Cover
National Aluminate Corporation..... 16
Northern Equipment Company..... 2
Poole Foundry & Machine Company..... 44
Prat-Daniel Corporation.....Fourth Cover
Reliance Gauge Column Company, The..... 40
Vulcan Soot Blower Corporation..... 15
Yarnall-Waring Company..... 52



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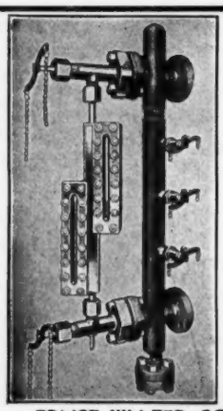

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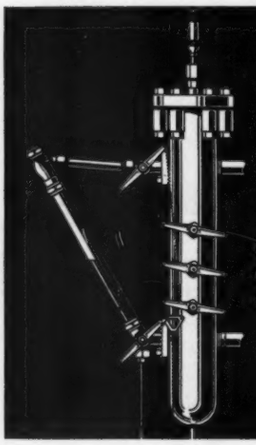

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